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BY

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lation is very poor, and that the continual whipping of the stuff dulls the colour and spoils the purity of the paper.

We have described our ideas of a hollander beater in some detail, but experience shows that if the maximum efficiency is to be obtained, great care must be paid to details of design and dimensions.

For a hollander holding 450 lb. of dry stuff and intended for general use, such as the beating of wood pulp, wood and 'broke', wood and rag and all rag furnishes, the weight of the roll should not exceed 3 tons and the circumferential speed of the roll should be about 2,000 feet per minute.

The Umpherston beater differs from the hollander in that it is placed 'on end' to save space; in other words, the stuff travels down from the roll and underneath it, and then up and back again, instead of round the trough. The midfeather is placed under the bedplate and the roll is well out of the stuff.

We are of opinion that there is little to choose between a well-designed hollander and an Umpherston, but the latter has three distinct advantages—namely, its saving of space, its easier and quicker emptying facilities and its freedom from 'lodgers'; it is also much more shut in—that is, the stuff is not nearly so exposed to the dust and dirt which are continually falling about in a beater room, as is the case with the hollander. Owing to its being so much enclosed, when beating hard fibres, the stock heats up very quickly.

The Umpherston is a compact, well-designed and thoroughly efficient beater.

The Taylor beater (Fig. 54) is used principally in mills whose furnishes contain a large proportion of esparto.

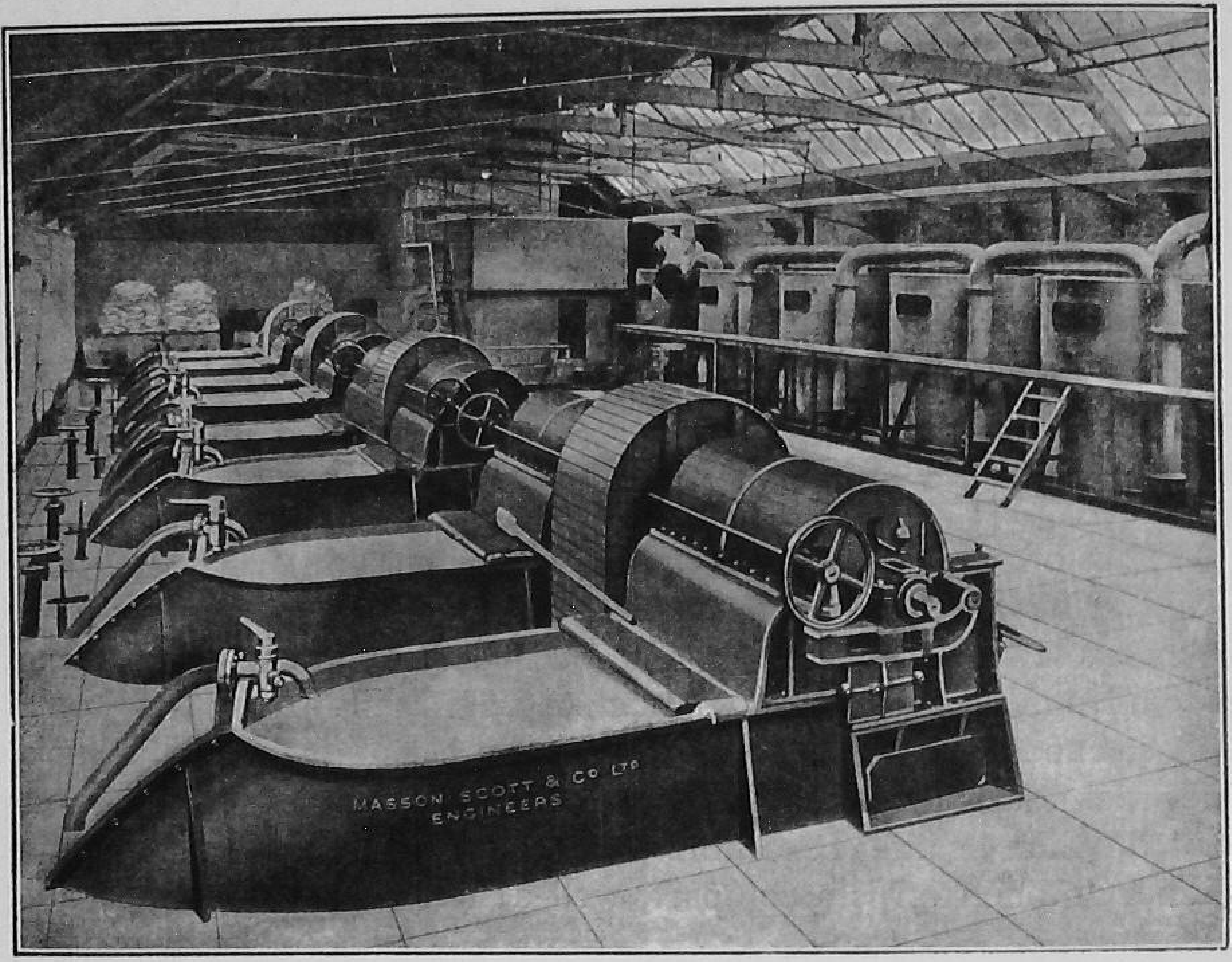
In beating such stock as esparto and wood it is possible to dispense with those factors which are an absolute necessity for beating strong rag stock. The ultimate fibres of wood and esparto are short, and if the papers made from them do not require to be very strong, their treatment in the beater is sharp and quick, and must be as uniform as possible in order to produce a very close and evenly made sheet.

The Taylor beater fulfils these requirements admirably, and is being successfully operated in many mills making esparto papers. The beater is entirely different in construction and design from both the hollander and Umpherston types, as will be seen from the illustration.

The stuff is fed into the vat and drops down to the bottom of the enclosed trough, where it is collected by a centrifugal pump, and forced up again through a pipe, to be discharged in front of the roll.

This method of circulation relieves the roll of the necessity of performing the whole of the circulating or propelling of the stuff, and therefore the roll

may contain many more bars, and these may be closely and evenly spaced. It will be evident that this process ensures quick and uniform beating of the



[*Masson, Scott & Co. Ltd.*

Fig. 54.—A Battery of Taylor Beaters, with a Range of Bleaching Towers in the Background

stock and saves a large amount of time. The roll is also much smaller and lighter than is necessary with the hollander.

This type of beater is not suitable for the treatment of long-fibred stock, such as rags, as the circulator will not deal with such material, and in any case the treatment of rags with such an arrangement of beater roll would not be satisfactory.

The Taylor beater does not necessarily depend on gravity for discharging the stuff to the chests, as, by the arrangement of cocks and emptying pipe, the stuff can be pumped by the circulator to the machine chests, so that the beater may be on the same floor level as the machine, if necessary.

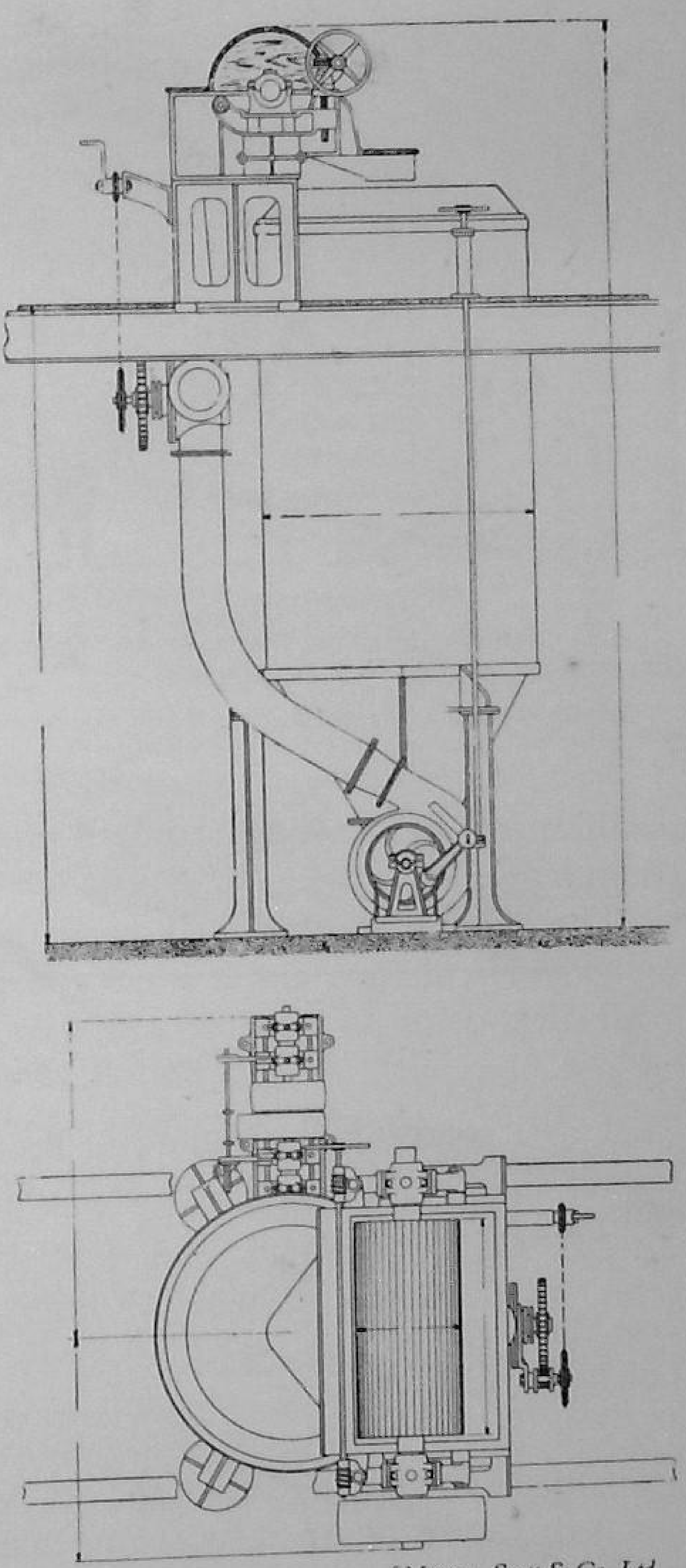
Very little floor space is required for this beater, and, being enclosed, the stuff is not exposed to dust and dirt from the beater room. The roll and plate are fixed to the floor of the beater room, independently of the pan, in a square casing.

Another beater of a slightly modified design, but working on the same principle, is the Tower beater (Fig. 55), made by Masson, Scott & Co. Ltd. It differs from the Taylor beater in that it occupies less floor space in the beater room, and, being supported usually from the ground floor, the beater room floor can be of much lighter construction.

The stuff is discharged from the roll down on to a conical hood fixed at the top and inside the tower. This spreads out the pulp and mixes it continuously during the whole of the beating. The bottom of the tower tapers down to a bend, at the end of which is fixed the circulating pump, which throws the stuff up a pipe and discharges it again in front of the roll.

The beating is performed in the same way as in the Taylor beater, and the same remarks apply as to the roll and emptying of the stuff.

The pump circulator of the Taylor and Tower beaters is a great help with short-fibred furnishes such as esparto, since it materially helps 'wetting', and in fact the roll can be lifted quite clear and the circulation by the pump will induce quite a large degree of wetness. Furthermore, the beaters may be filled with stuff of comparatively high consistency, and this is a great help in beating esparto furnishes to a given length and wetness. Unless a Tower beater is filled to a point below the conical hood 'lodgers' will collect above and cause trouble.

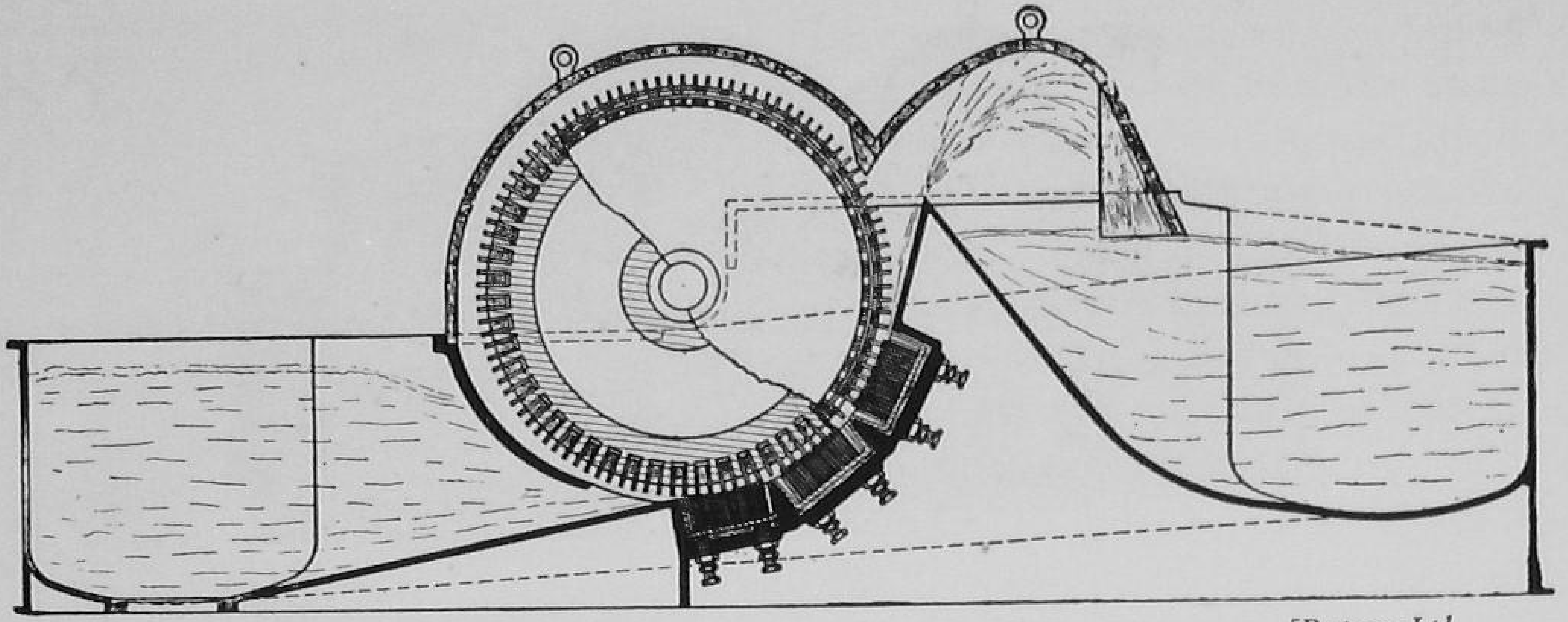


[*Masson, Scott & Co. Ltd.*

FIG. 55.—ELEVATION AND PLAN OF THE TOWER BEATER

The Sciennes patent beating engine, evolved after careful thought and

trial by Samuel Milne, is a great advance in beater design, and is giving good results on a wide variety of furnishes. Of the hollander type, it has several



[*Bertrams Ltd.*

FIG. 56.—SCIENNES HOLLANDER BEATER, SHOWING THREE BEDPLATES PLACED UP THE BACKFALL, AND EQUALLY SPACED BARS ON ROLL, AND VERY HIGH BACKFALL

The path of travel of the stuff is clearly shown, also the unusual shape of the wooden cover. Note the baffle plate in front of the roll, to prevent the roll from splashing in the stuff before it reaches the plate.

modifications of the usual standard models, and some innovations (see Figs. 56 and 57).

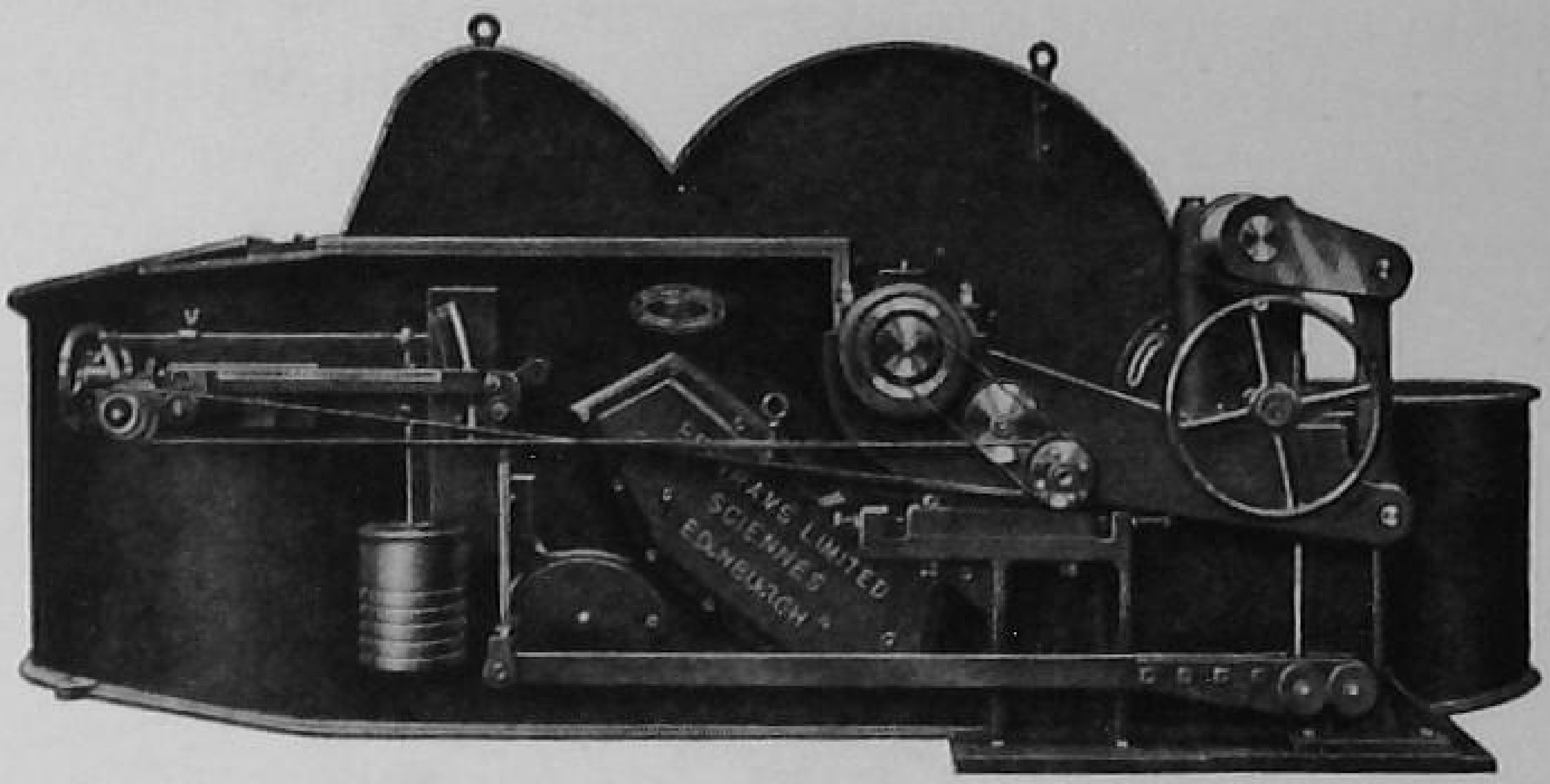
The trough is extremely well designed, in order to promote rapid and even circulation, and it is not the usual '2 semicircles joined by 2 sides', in which a great deal of stuff either lodges permanently until moved on by the potching stick, or only moves very slowly. The shape of the trough is shown in Fig. 49, and paper-makers will see at once that the 'dead spots' in their beaters, which they have often had to fill up with concrete, have been entirely eliminated.

The height of the trough is arranged to coincide with the general height of stuff as it travels round the beater, and it is low in front of the roll and high behind the backfall.

The roll itself is very heavy (9 to 10 tons in a 1,000-lb. beater), and the roll bars are equally spaced and not set in clumps. The reason for the heavy roll is to give pressure on the bedplate, and to prevent jumping and vibration when lumps of stuff pass through, while the fine adjustment provided for lowering the roll prevents all risk of the roll being too suddenly or heavily let down on to the bedplate. A heavy roll is better for beating strong stuff, which has to be well fibrillated, than a light roll, for it is steady and can be kept at a correct distance from the bedplate all the time.

As it is impossible for a beaterman, who has a battery of beaters to super-

vise, to operate them all in exactly the same way each time, an automatic operating gear has been fitted.



[*Bertrams Ltd.*

FIG. 57.—SCIENNES PATENT BEATING ENGINE, SHOWING AUTOMATIC CONTROL GEAR

The front main lever is operated by compound levers, and the weight is adjusted by hand wheel and screw, so that any desired pressure may be applied. The pressure may be maintained constant from start to finish if need be, but can be easily adjusted to suit requirements.

The bars, as mentioned above, are equally spaced and not clumped, as has been the usual practice for many years. The reason for this is obvious, for, as every beaterman knows, the first bar of the clump carries most of the stuff and the following bars not enough. Well-separated single bars, especially for long stuff, are the best.

Eighty-eight bars are fitted in this beater roll, which is 60 inches in diameter, and this gives about 2-inch pitch. As a general rule, a bar with a wide edge would be most suitable for beating strong stock which had to be well fibrillated, and a narrower bar for short, free stuff. The wider the bar the greater will be the pressure and crushing action exerted upon the fibres, but a thick bar can be made to cut up stuff quickly enough, provided it is lowered down quickly and kept hard on for a short time.

There are two or three bedplates which together equal about one-quarter of the circumference of the roll, and these, together with the weight of the roll and the well-designed trough, are responsible for the efficiency and great economy of power achieved with the beater.

The chief reason for making the bedplate so wide is that it is now realized that a large amount of the power consumed by a beater is used in circulating the stuff. In other words, it is wasted so far as actual beating is concerned.

As the beating is done only during the quick passage of the stuff between the bars of the bedplate and the roll, the way to increase the amount of beating done in a given time is to increase the size of the beating area—that is, the total area of bars in the bedplate and the area of bars in the roll.

The position of the bedplate is also different, in that it starts almost exactly under the centre of the roll and takes the place of the usual backfall up to a point. The short backfall takes up an angle of 15°, and is arranged to ensure the pulp being thrown out at the proper place. It will be readily understood that, with this design, the stuff is thrown clear immediately it leaves the last bar of the bedplate, and there is no heavy pocket of stuff lying between the backfall and the roll, impeding the passage of the stuff back into the trough.

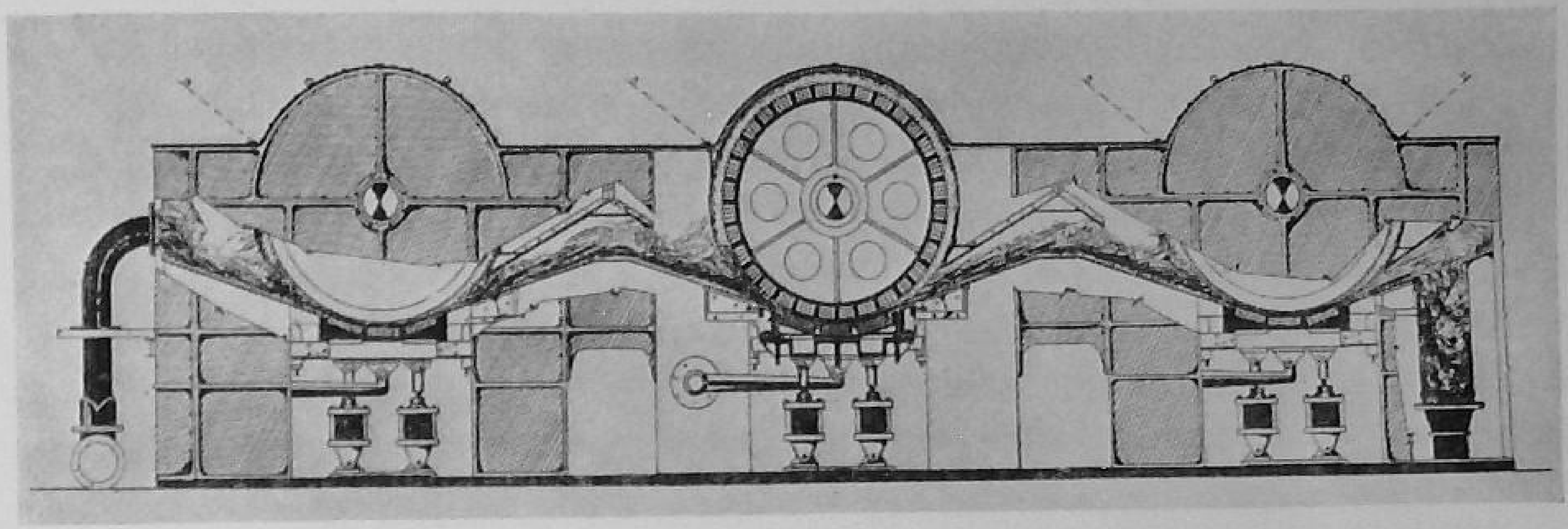
With the usual type of bedplate and backfall, stuff is flowing into the spaces between the bars all the way up the backfall, and being thrown out again by centrifugal force. This not only impedes the forward flow, but also adds to the power required to drive the roll, and instead of the stuff being quickly got rid of once it has received its treatment, as in the present beater, it is slowly pushed up in rolls to fall over the top of the backfall and into the trough.

In order to obviate the objectionable splashing of the roll in a deep pond of stuff immediately in front of the bedplate, a baffle board may be carried right down to within about 12 inches of the bedplate, and the floor of the trough is shaped up to the bedplate, so that the stuff is forced through this narrow space in sufficient quantity to allow of a fibrage being taken on by each bar of the roll. A smaller opening than 12 inches would be sufficient, but lumps of stuff would be liable to choke it when furnishing.

Modern beaters are designed to circulate in the quickest possible time, and at the same time to possess a large bedplate area in order that a greater amount of work may be done during one circulation of the stuff. This is done by having a very wide bedplate, or more often by having a series of bedplates. There is also a tendency at the present time to use lighter rolls, as it is claimed, apparently with some authority, that the work can be just as well done with lighter rolls and less power.

The Multi Roll Controlled Flow 'Victory' beater, made by the Noble & Wood Machine Company, has recently been put into production and is being used with success in the making of kraft in America. The results obtained with this beater seem to give a very appreciable saving in power and a big increase in the bursting strength and tensile. Actually, this multi-roll beater is like three separate beaters connected in series, each unit consisting of a roll and bedplate, between which the pulp stock is given the

desired degree of treatment according to the amount of pressure applied by the hydraulically operated bedplates which press up against the roll. The



[Noble & Wood Machine Co., Hoosick Falls, N.Y.

FIG. 58.—THE CONTROLLED FLOW VICTORY BEATER, WITH THREE ROLLS AND HYDRAULIC BEDPLATES

flow of stock is discharged from one unit directly to the next in a continuous uninterrupted stream, without any vats in between, and the fibres can be subjected to as much pressure as they will stand, as it is possible to give much higher pressure by means of the hydraulically operated bedplates than that developed by the dead weight of the roll. In this case the roll is mounted in roller bearings in a fixed position, and very high total pressures can be brought to bear between the bedplates and the roll. The illustrations show clearly how the stuff passes through this machine, and also how the hydraulically controlled bedplates are operated (Figs. 58, 59 and 60).

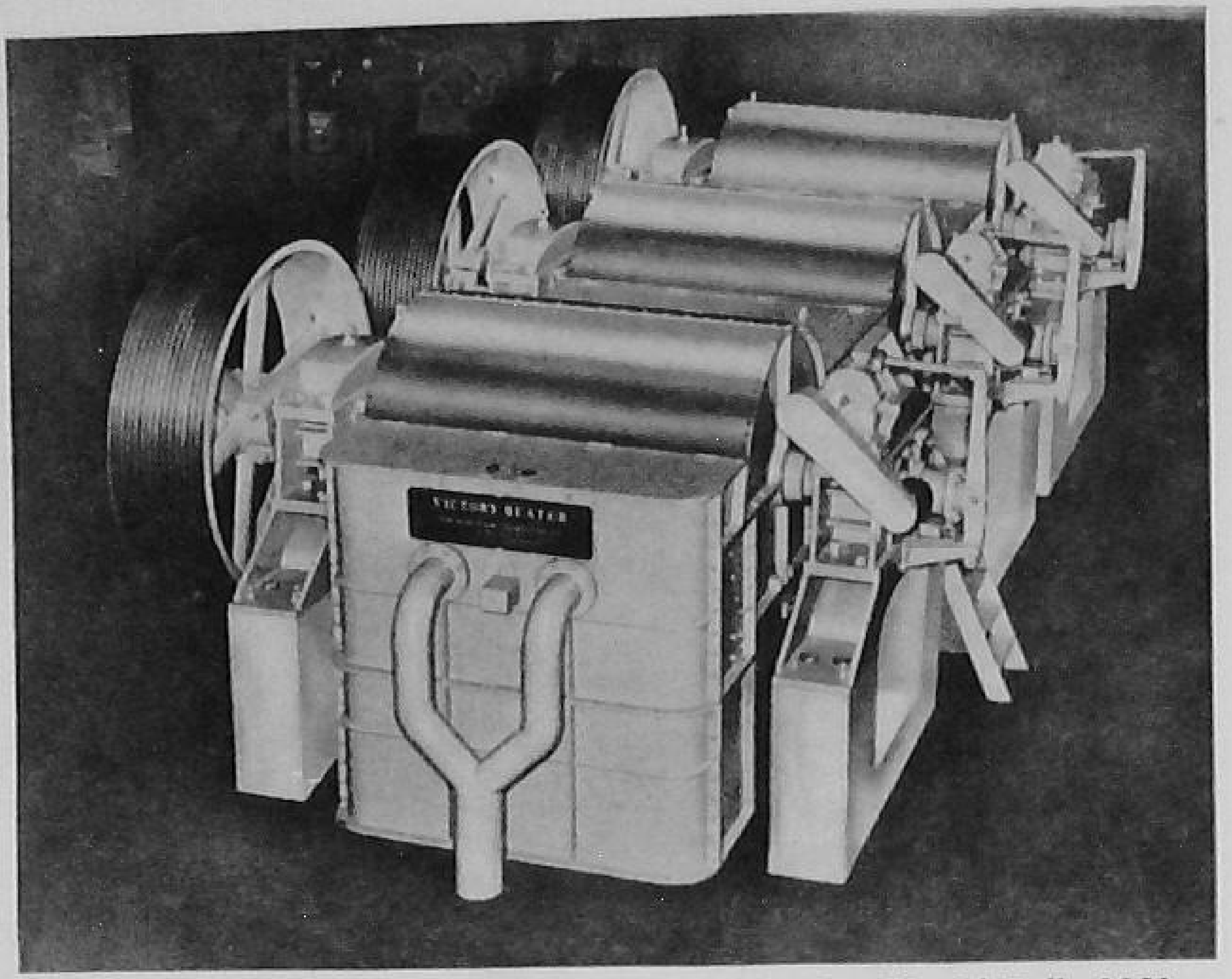
This, of course, is not the first time that hydraulically operated bedplates have been used to obtain the pressure between the roll bars and the plates, as there have been other examples of this during the last forty years or more; but it appears to be the first time that a continuous beater of this description has been used with success.

The 'Victory' beater with hydraulic bedplates is, of course, made as an ordinary beater as well as a multi-roll beater, and the tub can be built to meet any conditions which obtain in the mill.

By using a propeller to control the flow of stuff to the beater roll, and also a valve, any predetermined quantity of stuff can be passed to the roll, and this can be varied at will.

The main feature of the 'Victory' beater is that it is so designed that the roll is not in the tub itself, and therefore it is not required to perform the multiple duties of circulating, mixing and beating. It is mounted in an elevated position, and is held solidly in fixed anti-friction bearings. It is also provided with a timed oscillating movement designed to keep the bar

surfaces smooth, free from ridges, and thus also to avoid 'shoulders' on the bedplate ends as wear progresses. The roll performs one function only—



[*Noble & Wood Machine Co., Hoosick Falls, N.Y.*

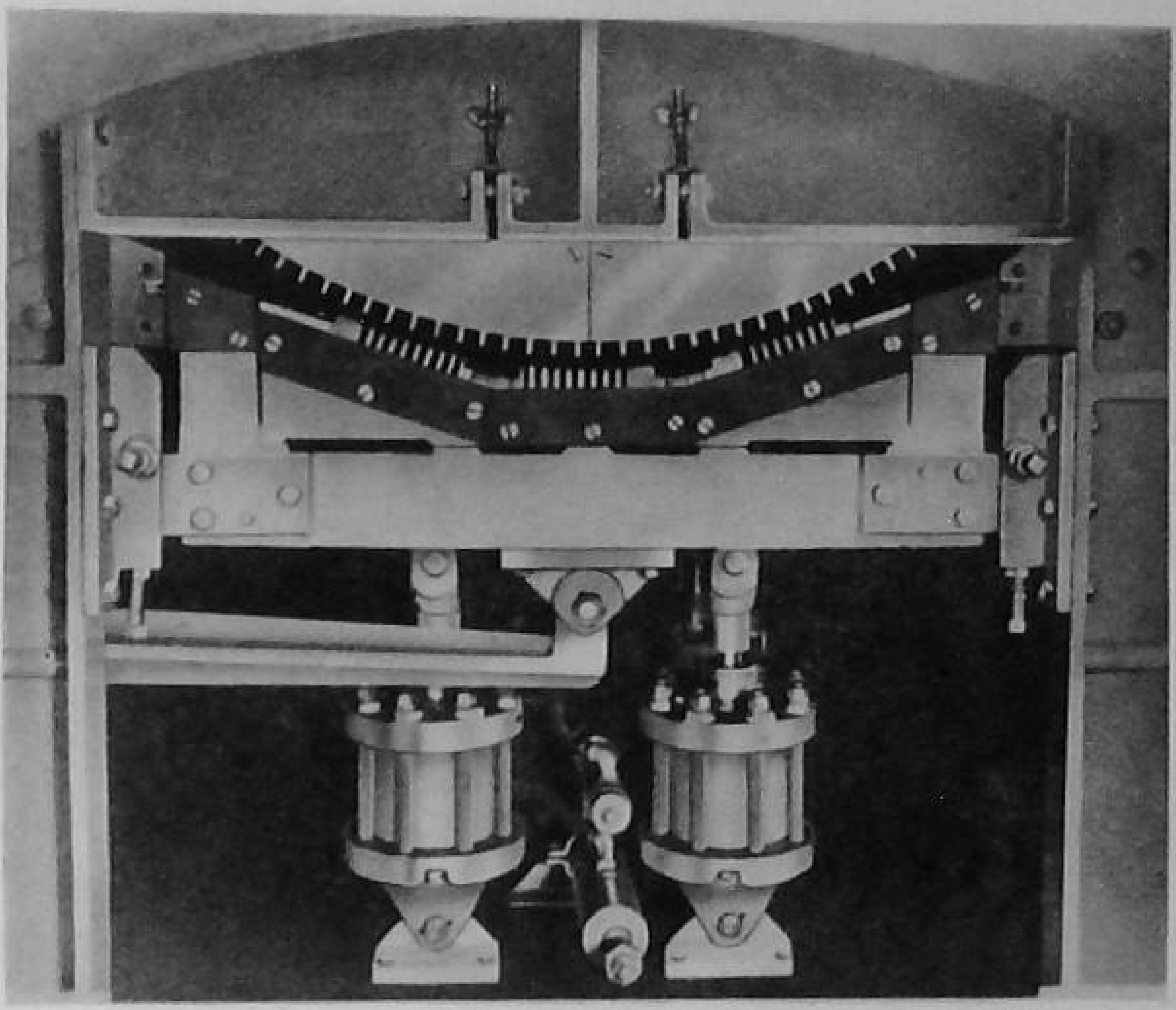
Fig. 59.—Noble & Wood Victory Beater showing Drive and Stuff Inlet Pipes

that of fibre treatment—and practically all the power transmitted to the roll is expended in treating the fibres.

The Thorsen-Hèry beater (Fig. 61) works on an entirely different principle from the hollander, the roll revolving in the opposite direction to the flow of the stock, and carrying the stuff upwards past the bedplate instead of underneath and over the bedplate as in the hollander arrangement, and then up the backfall and over into the trough again. In the case of the Thorsen beater the stuff is delivered after passing the bedplate into a receiving basin above the level of the trough; and from here it runs down by gravity into the trough again. It will be seen, therefore, that the stuff is in far shorter contact time with the roll than is the case in the hollander beater. The design of the Thorsen beater allows for the roll to be carried in a fixed bearing permitting the direct connexion of motor through reduction gears. There is also the minimum baffle area in front of the roll, and thus a good deal of power is saved, which, in the hollander, is expended on beating the stuff which is still in the trough. The pressure in this beater is applied by a compressed air cylinder or, alternatively, by levers and weights. There is also raising and holding gear with micrometer adjustment indicating the space between roll and bedplate.

Beating

Among all the various processes which are used in the manufacture of paper, none has aroused so much controversy and discussion as beating.



[*Noble & Wood Machine Co., Hoosick Falls, N.Y.*

Fig. 60.—The Hydraulic Gear operating the Three Bedplates of the Victory Beater

'What takes place in the beater?' is still a question that has not yet been answered to the satisfaction of the chemist, the engineer and last, but not least, the paper-maker.

We propose, however, as paper-makers, to offer an explanation as the result of our experience, aided by the results of the investigations of those who have of late years devoted so much time and careful thought to the subject.

At the outset we propose to divide the subject into two phases, 'free' beating and 'wet' beating.

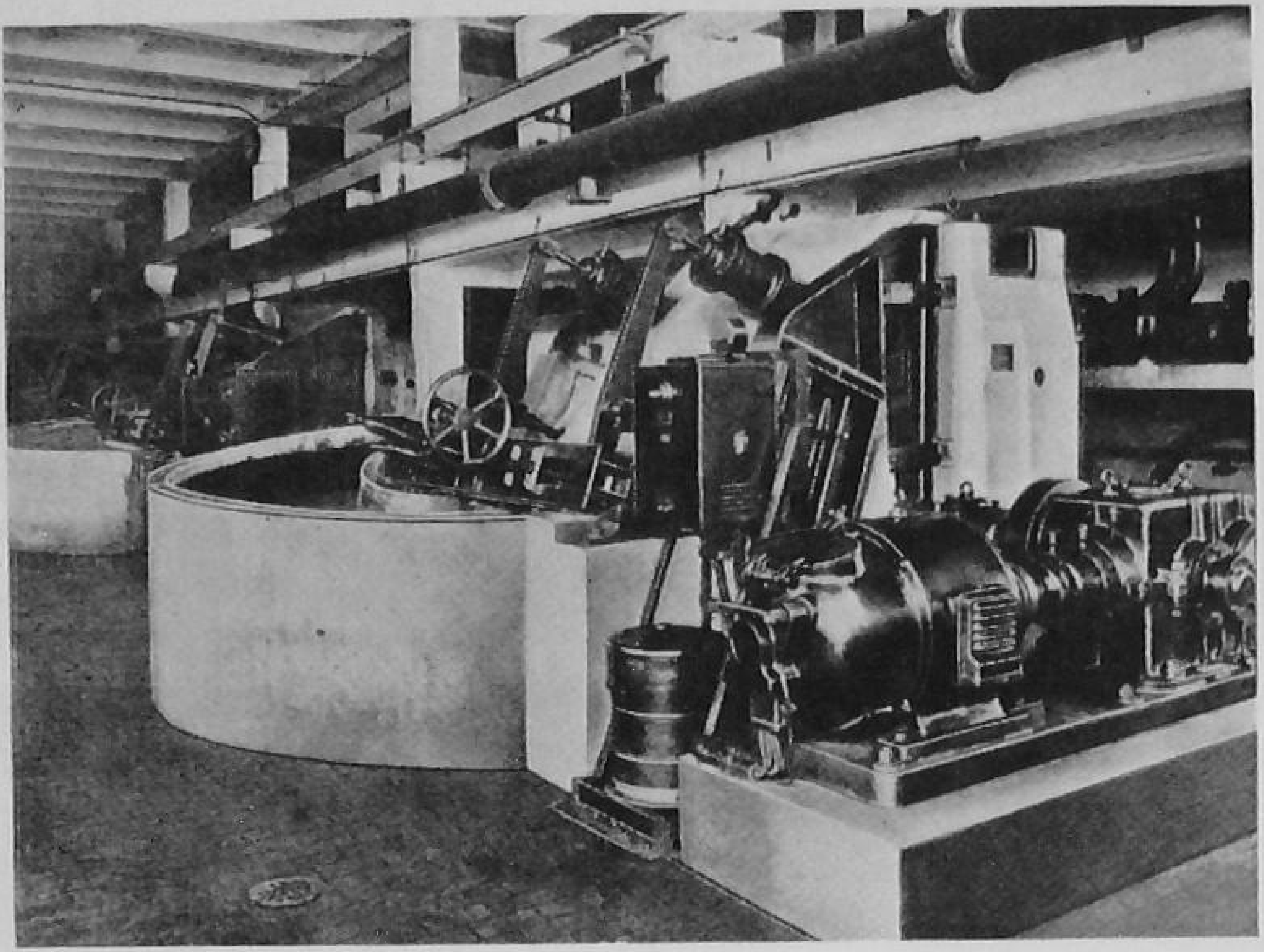
By 'free' beating we define those processes where such fibres as mechanical wood, esparto, straw, etc.—very short and poor in themselves—require no more than to be separated from clumps or clusters, and are sent in almost, if not quite, their original forms to the stuff chest.

The term 'free' we regard as denoting the result of this elementary 'beating'. The fibres, when passing over the wet end of the machine, part from the water, in which they float, easily and freely.

The power required for treatment can be calculated, and special engines,

such as the refining engine, can be used to achieve successful and satisfactory results.

The action of these special engines is not, in the true sense of the word,



[Bentley & Jackson Ltd.

FIG. 61.—THE THORSEN-HÈRY BEATER, WITH HYDRAULICALLY LOADED PLATES PLACED ABOVE THE ROLL

'beating', although there is no doubt that some actual beating can and does take place when the fibre is of such a form and structure as can stand it. This class of beating suffices for newsprint and other printing papers, and also for all those papers made from esparto with a *small* percentage of chemical wood. It is when we come to deal with papers of a better class, such as writings, banks, ledgers, cartridges, tissues, and 'manillas', and, in fact, most papers that require to be water-marked, or to have strength, transparency or any other special feature, that the second phase of beating becomes of paramount importance. Then, in various degrees, the stuff must be what has been called by the older paper-makers 'beaten wet'. We by no means dismiss the first class of beating—namely, what we call 'free'—as of no account or unworthy of investigation, but will confine ourselves to the second class, as being what is admitted by all concerned to be the representative process for all 'beating'.

When the first prehistoric member of the Paper-makers' Association started to make paper he found that one part of the process entailed a great deal of heavy work, and no doubt delegated the pounding or beating of the

fibres to his sturdiest employee. Up to the present day, to produce a strong paper from 'rags'—we will assume this to be a representative of the whole class—the greatest power is consumed by the beating process. To reduce this great consumption of power, to 'beat' the rags to produce what we require, with the minimum expense for fuel, is the ultimate object of all investigators of the process.

Before we can do this, we must find out what takes places in the beater. We can do this only by examining results, and formulating a theory which will agree with these results. Now it is agreed that if two beaters furnished with identical quality of stuff are run off at the machine, and one is beaten 'wet' and the other 'free', the one that is called 'wet beaten' invariably produces the stronger paper. This brings us at once to the point where we must define what we mean by 'wet beaten' stuff. In a word, it is stuff which parts with its water very slowly. It will go from the breast to the suction boxes without losing much of the water in which it is suspended.

When passing over the suction boxes a high vacuum is required to withdraw sufficient water to allow the web to be couched without being crushed. This is what a machineman will understand by 'wet' stuff, and for practical purposes the word will express the idea to most paper-mill men. However, for more scientific men the word did not correctly define the condition, and they renamed it 'hydrated' stuff, a word which really means 'combined with water' in a chemical sense.

The question then arose as to whether this so-called combination of stuff and water is caused by the mechanical action of the beating engine or by some obscure chemical process.

The theory of 'fibrage' pronounced by Dr. Sigurd Smith was hailed as a great discovery by the paper-making world. Without in any way wishing to detract from the value of this investigator's patient labours, we are of the opinion that he leaves us, for any real explanation of the subject, just where we were before. He has not shown us how to beat stuff 'wet', or *hydrated*, by using less power.

He does indeed indicate how power and time may be saved by using two plates, and causing one circulation of the stuff in the engine to give results hitherto obtained by two circulations, but the fact remains that the actual power that is necessary to 'beat' remains the same. He gives us no explanation of beating which will enable us to get 'wet' or 'hydrated' stuff by any other means than the beating engine.

As for the 'chemical' or 'physical' question, we should think that, after the published results of the researches by James Strachan, no one will

seriously claim that chemical combination of stuff and water can take place, except in an extremely limited degree.

This being so, we venture to assert that the term 'hydrated' stuff is misleading and erroneous. It has been presumed that stuff must be wet or hydrated before it is in that condition which makes the strongest paper.

Mr. Strachan, in our opinion, conclusively proves that 'hydration' is merely the *sign that the stuff has attained that condition*, and our personal experience in beating entirely coincides with his proof. He shows that when the fibres are subdivided into *fibrillæ* and partly crushed into very fine particles, more water adheres to their surfaces, or that the mixture of stuff and water has become more intimate; each minute particle of stuff has its *superficial area increased by subdivision*, and that additional surface area is covered by a film of water. Therefore, the fact that extra water has been attracted to the stuff is not the reason why the paper will be stronger, for the strength is caused by the fibres being '*fibrillated*', and this, we think, is the proper word to describe the condition.

It can certainly never be asserted that water adds strength to fibres; therefore it must be that they gain strength by being *fibrillated*.

Now let us describe what does actually take place in the beater from this standpoint. We will presume that we have got a hollander furnished with linen fibres. This stuff has been boiled and gas-bleached to remove all shive.

We may presume that in these processes the fibres have been thoroughly saturated with water. Indeed, it is inconceivable that thorough saturation has not taken place. Every pore, canal and surface of each individual fibre has its full quota of water; yet it cannot be said to be *hydrated* in the true meaning of the word.

To return to the beater. We know that if we simply clear the fibres of knots, etc., and run them over the wire, the sheet will look raw and cloudy, and the fibres will be too cumbrous to felt with each other, and may be easily pulled apart. The dandy roll will be unable to make a proper impression on the sheet. Therefore we have to '*beat*' the linen fibres—and 'linen takes a lot of hammering', as every beaterman knows—in other words, we must have the fibres well *fibrillated*. If our beater bars are too sharp we have great difficulty in fibrillating the fibres; instead, we may cut them and have free stuff, which is not at all what we set out to obtain. But if our tackle is dull—that is, the plate is well worn and the bars are blunt—we can put our roll down on the plate. Then, whether through fibrage on the bars, or the stuff being drawn through by the vacuum of the beater-roll spaces, the process of 'fibrillation' commences. As every beater bar passes the plate, so many fibres

will be struck and bruised between the flattened surfaces of the bars and plate.

If a fibre is struck longitudinally, it may be divided into several fibrillæ; if across, it may still be fibrillated where the blow falls, thus exposing more surfaces to the water in the beater. But it is bound to be the case that many fibres will be so heavily struck that they will be partly fibrillated and partly bruised; the bruised portion will give up some of its particles to float in the general mass, other particles remaining attached to the fibrillæ. If the beater is run long enough, all the fibrillæ will in time be crushed into these fine particles and become quite useless for paper-making. Therefore, our object is to stop the action when we have most fibrillæ and a good proportion of these particles amongst them. Our engine of stuff will be fully fibrillated. These fibrillæ and many fibres partly flattened, and some cut through with fibrillated ends, are obviously what will interlace to make a tenacious sheet, and the finer particles will settle into the minutest spaces between the larger fibres and still further entwine them together.

By this latter action we lose bulk but gain strength, solidity—shown by hardness of rattle—and transparency. Now in the making of our fibrillated stock into paper our greatest difficulty lies in getting rid of the extra water carried by the stuff. Some is drained out by the action of the tube rolls of the wire, some is drawn out by the suction boxes and suction couch. The pressure of the press and couch rolls accounts for a great deal. But all the extra surfaces of the fibrillated fibres retain some surface water, and part with it only by evaporation on the hot drying cylinders.

It simply amounts to this: we have to dry a much greater surface area when the stock is highly fibrillated than when the stuff is free beaten.

Again, it is a matter of great difficulty to run heavy substances, say 72 lb. Imperial, when using a rag stock highly fibrillated, to produce a strong paper. The maximum strength obtainable from the stock is limited to the capacity of the machine to extract this unwanted water on the wire before the couch nip—that is, the stuff must, in most cases, be let down to the chest before it has been beaten long enough to get all the good out of its fibrillating capacity. To overcome this difficulty it is common mill practice to use steam heat in the stuff and water. This is said to 'dehydrate' the stuff, but this dehydration does *not* reduce the strength of the paper. The increase of temperature reduces very greatly the viscosity of water, and it is this viscosity of water which is the cause of the trouble at the machine when making thick papers from highly fibrillated stock.

The finished sheet has its strength from the 'fibrillated' condition of its mass, which is the essential factor, and *not* from the water which has clung

to the fibrillæ, and, being only incidental to the condition, has been removed.

This explanation of what happens in the beater is supported by paper-making practice and common sense, and it seems to us that in no way, except by the exercise of power, can we achieve this particular condition of stock.

Refining

After stock has been beaten in the hollander or other beater of the same type, and before it can be let down to the machine chests, it is necessary to set the roll so as to 'clear' the fibres. This clearing consists in breaking or brushing out fibre clusters or particles of pulp or paper that have in some way escaped the action of the roll and plate, or have been packed into knots or lumps by the violence of the beating. The roll is raised so as to be just clear of the plate, and the beaterman uses the stirring-stick freely to turn up the stuff in those portions of the trough that experience has shown to have a sluggish circulation. The clearing proceeds until a sample of stuff examined in a hand-bowl shows no lumps or knots or paper 'bits'. This may take from 15 minutes to 1 hour, according to the fibres or stock being treated and how it was prepared previous to beating. Broke filled into the beater without preliminary treatment is very difficult to clear; in fact, sooner or later un-cleared bits, notwithstanding every precaution, will get to the machine chests and spoil the paper.

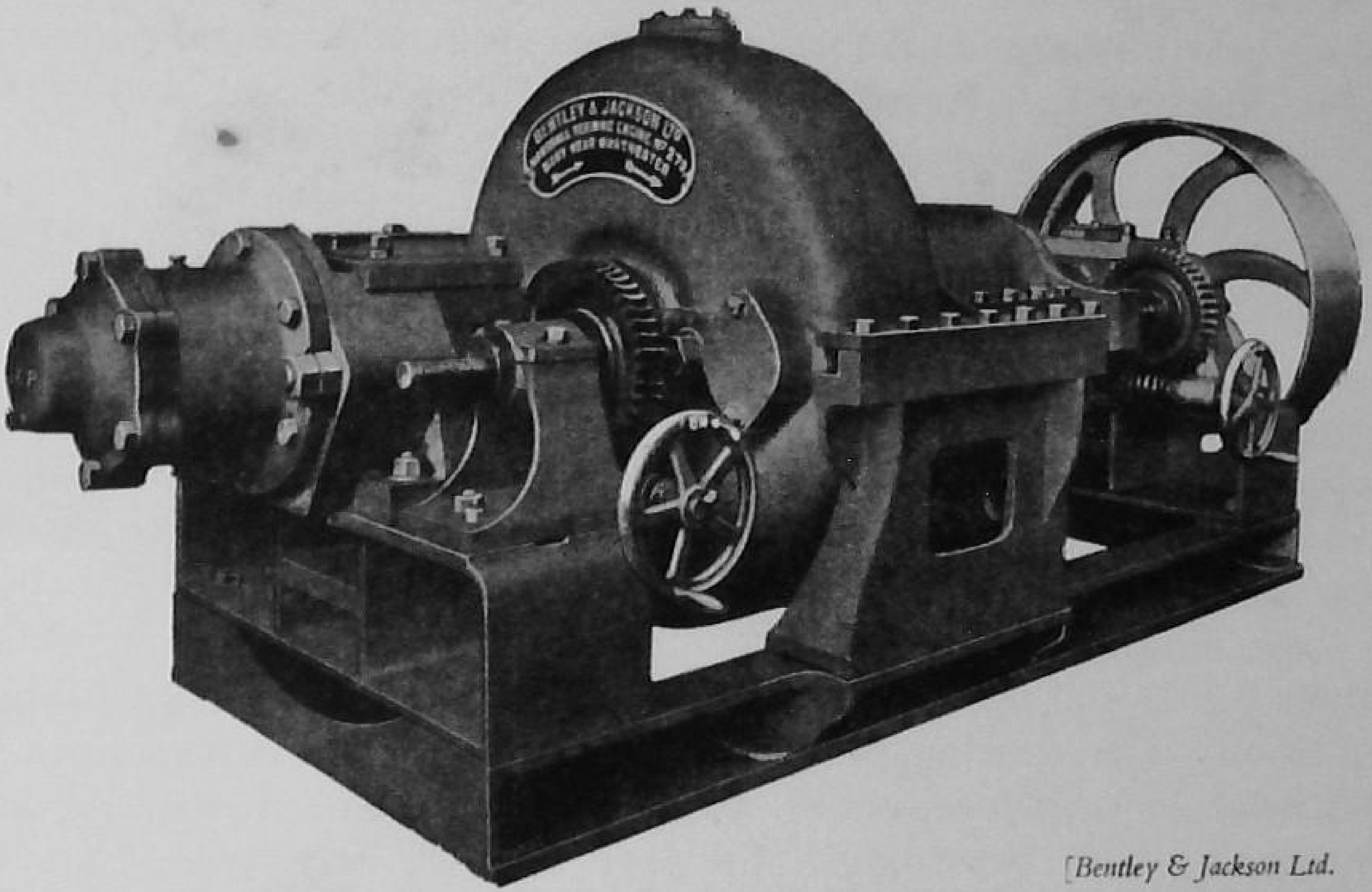
A lump of pulp or paper may lodge about the plate or backfall or stick about the bottom of the beater, and be flushed down to the chests when the beater is emptied. This danger, and the time and power required for clearing, brought the 'refiner' into being.

The refiner (Figs. 62 and 63) is a machine expressly designed for clearing beaten stock, and its proper working position is exactly the same as the beater roll 'clearing'.

When the beating proper has proceeded far enough, the action is stopped and the refiner takes up the work. Instead of the whole charge circulating round the beater, for the purpose of treating what is relatively a very small amount of stock, and consuming time and power, the charge is let down to the refiner chest, the stuff is immediately started on its way to the machine, and the beater is refilled.

The refiner usually consists of a cone-shaped shell or case on the inside of which are set, longitudinally, bars similar to those in a beater plate, with knees or zigzag formation. An internal conical rotor fitted with straight bars is mounted on a shaft so arranged that the bars may be brought into close

contact with the bars on the inside of the outer shell. In some refiners there is also a disc with corresponding blades on the rotor disc. The central rotor is



[Bentley & Jackson Ltd.

FIG. 62.—THE MARSHALL REFINER, DISC END

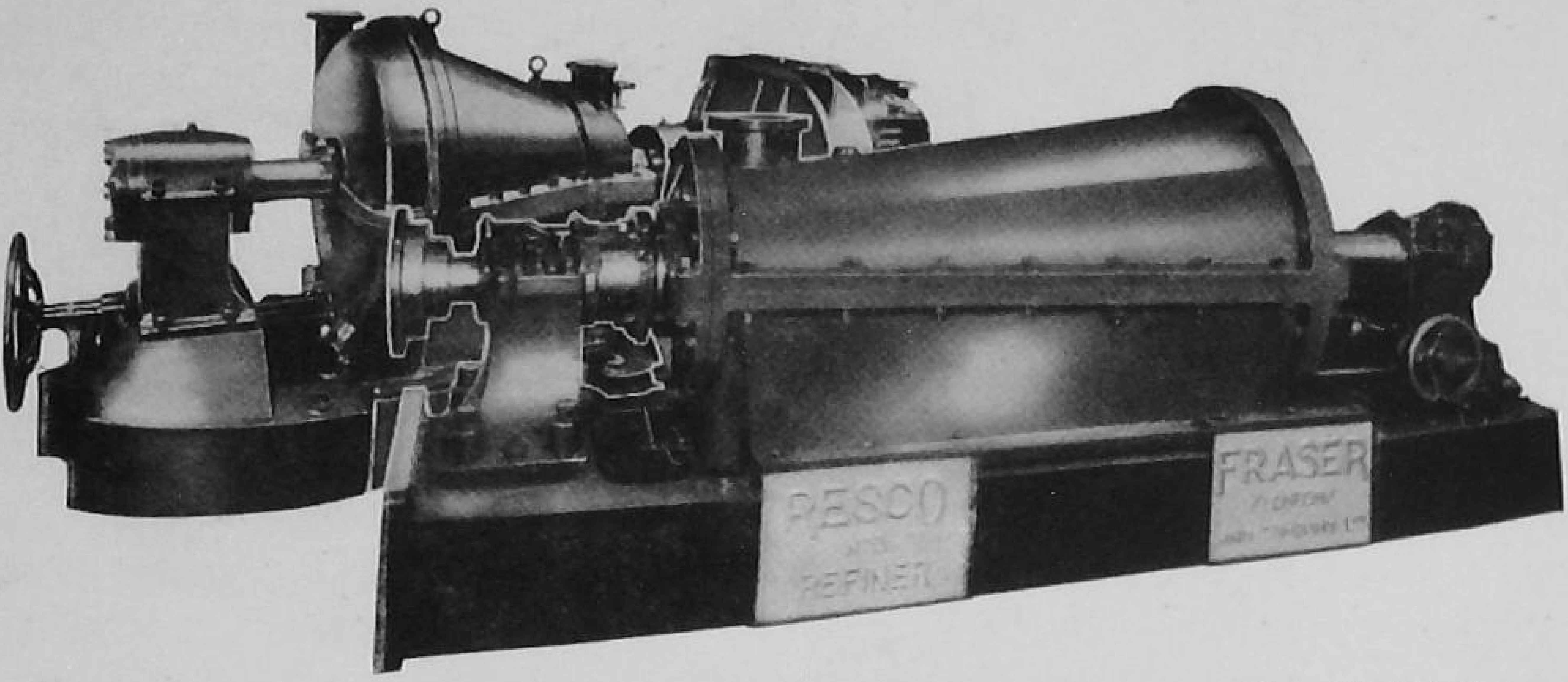
This refiner has a disc as well as a cone, and the disc is chiefly used for clearing the stuff and freeing it from knots.

adjustable by a hand-wheel and traversing gear, which moves the shaft and cone into the outer cone, bringing all the bars on the rotor and disc into contact. The illustrations clearly show the arrangement of bars.

When properly set, stock that is clear passes readily through the machine without being cut or injured; larger or uncleared fibres, knots of stuff, etc., are caught by the bars and rubbed out or cut before they can pass through.

The stuff enters at the small end of the cone, and is discharged from a pipe on the circumference of the disc. It is obvious that the action can be made more drastic, though at a very great expenditure of power. The rotor may be pressed harder against the outer cone, when the refiner takes on the action of a beater with extreme cutting characteristics, especially as the stuff is at a much lower consistency than in the beater. To overcome this difficulty concentrators are sometimes used to extract water from the stock before it enters the refiner. After passing through the refiner in a highly concentrated condition, the stock and the extracted water are again mixed together. Under these conditions there is no doubt that fibrillation takes place with some fibres, notably those that are soft and well boiled. The fibres that are most successfully treated by refiners are, however, those that we have already

mentioned as requiring 'free beating'—that is, mechanical pulp, esparto, etc. The fibres from broke and waste paper, which have been already treated



[*Fraser (London) & Co.*

Fig. 63.—Two Types of 'Resco' Refiner

The one in the background has short steep cone; that in the foreground has a much longer plug.

for paper-making, and require only to be defibred, form another class which can be 'beaten' by the refiner, provided always that they are well saturated with water in the beater or breaker.

The use of the refiner has been extended in many mills using the above classes of stock, to cover nearly the whole of the beating, the beaters or breakers themselves being used for little more than the preliminary mixing of the stuff, alum, size, dye, etc.

The refiner being a modified type of beating engine, it is, of course, possible to beat certain papers by means of a series of refiners, the stock being passed from one engine to another. A strong 'bond' paper may be produced from chemical wood pulp in this way, especially successful being those mills which can get their pulp straight from the digester.

The refiner is a very excellent machine for certain purposes, if used with care and intelligence, but it can produce disastrous results if carelessly handled.

It is now the practice in some mills for the refiner to be placed in the machine house and under the control of the machineman. The reason for this is that it is becoming recognized that it is possible, by the use of refiners, to alter slightly the appearance of the sheet and also assist the machineman in closing up his sheet when necessary. Previously the use of a refiner was to clear the stuff after it had been taken from the beaters into a refiner chest;

the stuff then passed from the refiner into a machine service chest. The new practice calls for a different arrangement, which is as follows:

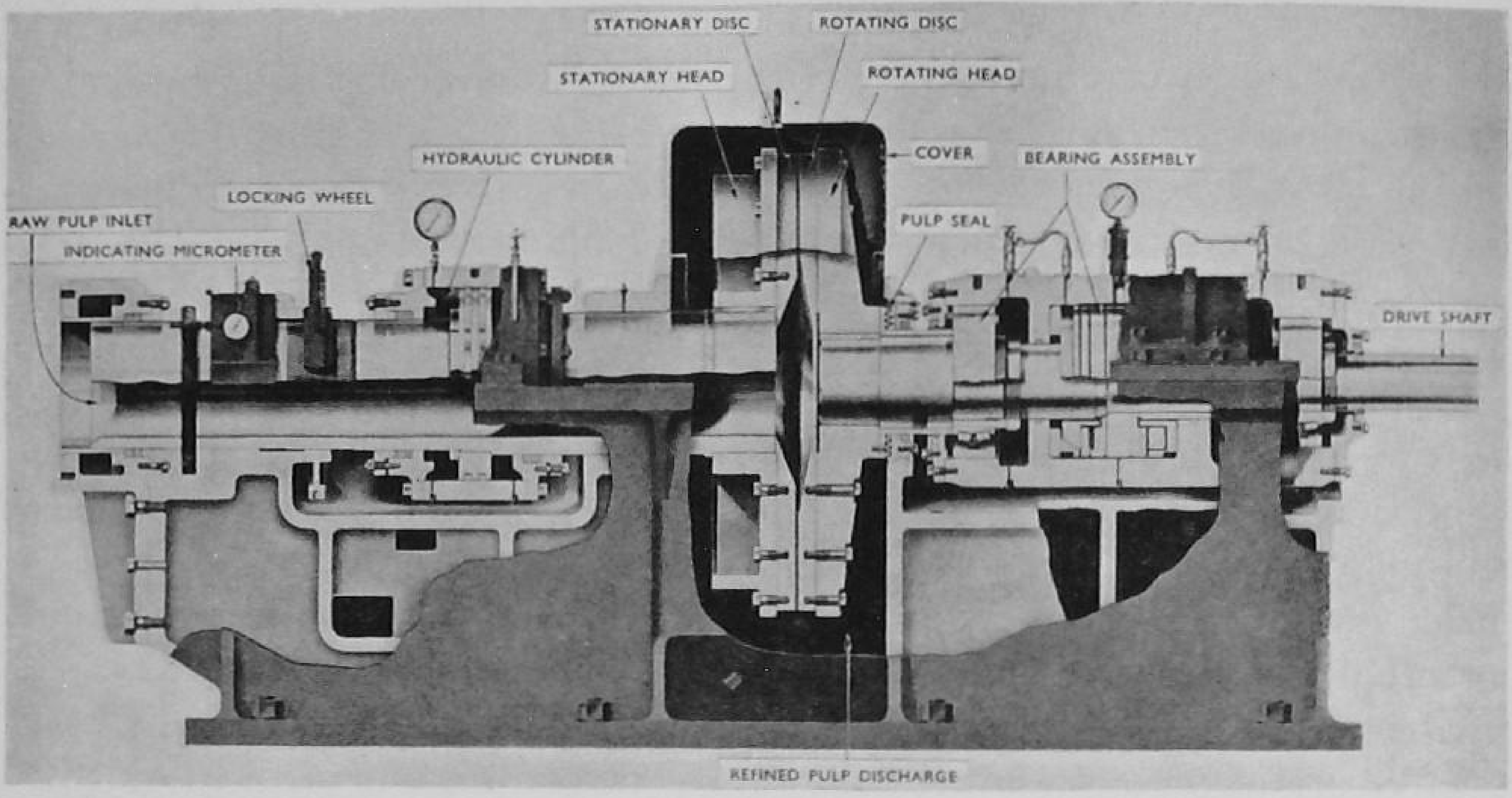
The refiner is placed after the stuff pump and immediately before the head box; the stuff is left slightly longer by the beaterman than would be the case if there were no refiner. The machineman on starting up examines the sheet and then sets his refiner to reduce the length of fibre if necessary, and to clear the stuff of knots. The beaterman is thus relieved of the necessity of clearing his engine, sometimes a long and difficult business with certain furnishes, and a lot of power is saved in the beater room. It was quite a common thing, especially in rag mills, for a knotty engine to be let down, and thus spoil a whole chestful of stuff. There was no alternative other than to run the stuff out as broke. With the refiner arranged as part of the machineman's equipment this is not so likely to happen, as the stuff from the knotty engine can usually be cleared in a minute or two. Further, the placing of a refiner in this position, where it deals with the stuff immediately before it passes on to the machine, gives a far better separation of fibres, and enables a much more close and even sheet to be made.

We are of the opinion that the time is not far distant when this method will be universally adopted for many classes of papers. The Marshall type of refiner (Fig. 62) seems to be peculiarly well adapted for use in this position, as it has the additional advantage of the disc as well as the cone.

Refiners have been developed in far greater detail, and for far more purposes, in paper-mills in the United States than in Europe, the Americans having definitely made up their minds that the refiner is a more economical proposition than the beater; hence there are a large number of different types made for specific purposes, with many varied types of shape and fillings, and these are nowadays nearly all made in stainless steel. In England it has usually been the practice for the refiners to be filled with phosphor bronze, but the Americans have given this up, and have settled down to various types of stainless steel, and they have also experimented with very varying speeds. It seems to be the practice to use higher speeds for softer stuff, and lower speeds where the stock is hard, such as rag stock and stock from hemp and flax. In the last few years several new refiners have been introduced in the United States, notable among which is the Morden stock maker, which has been a very great success in many mills making vastly different kinds of paper.

The Sutherland Refiner (Figs. 64, 65 and 66) is a single rotating disc refiner which has been in satisfactory operation for some years, and in the case of wood pulp it is giving excellent results on many different kinds of papers. This machine originally had a double rotating disc, but after many

tests and much research work the single rotating disc was adopted as giving by far the most satisfactory results and very big savings in power.



[*Sutherland Refiner Corporation, Trenton, N.J.*

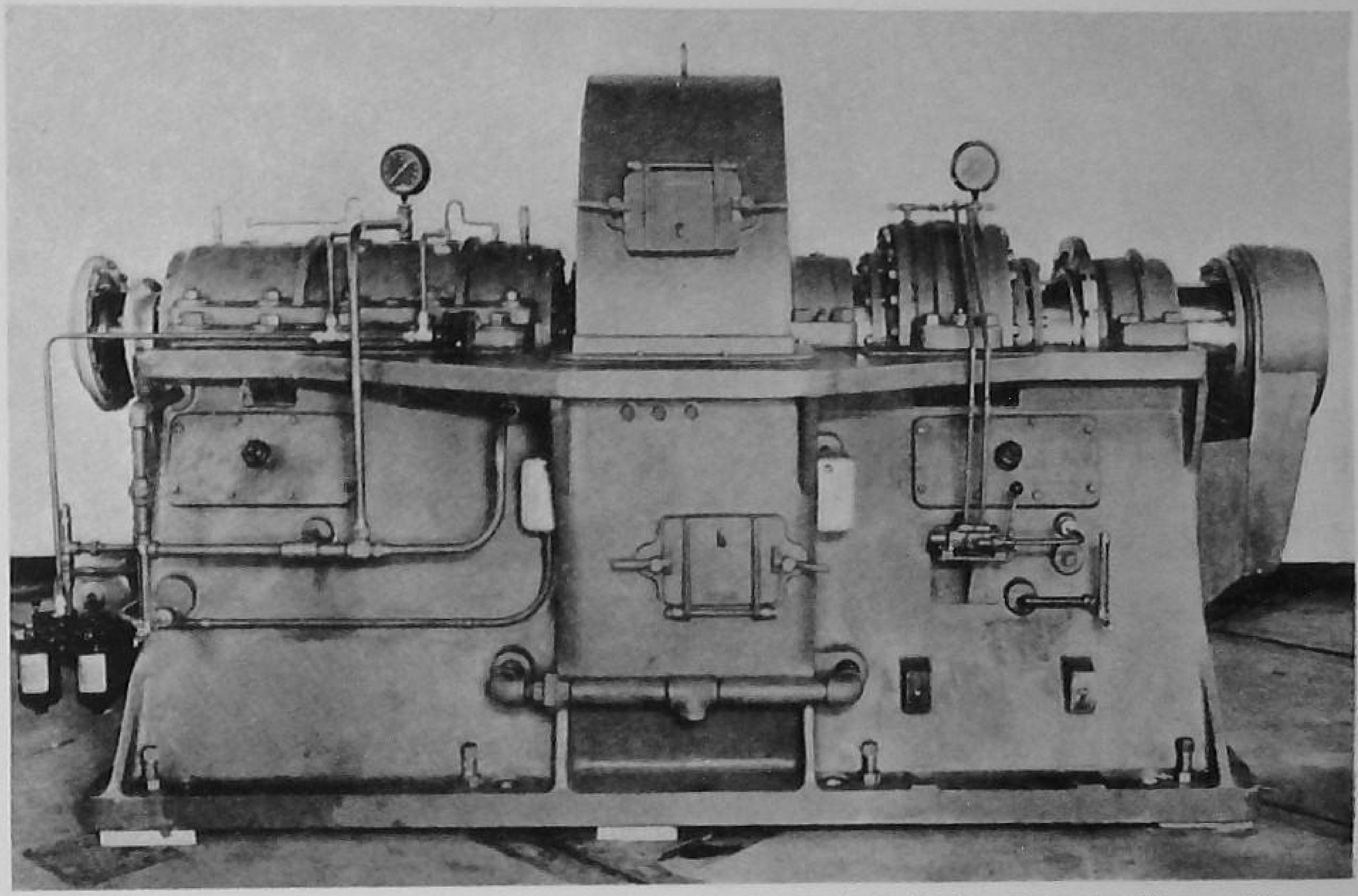
FIG. 64.—THE SUTHERLAND DISC REFINER, CUT AWAY TO SHOW ALL PARTS IN DETAIL

The relative positions of the discs are fixed for any particular furnish or class of paper, and the results obtained from the refiner, in the way of attrition and wetting, are varied by means of the pressure applied to the stock as it enters the refiner. This pressure determines the 'dwell time' that the pulp is retained in the refining area of the discs, in the same way as the work done by a beater is controlled by the length of time the stuff is left in the beater and the amount of weight applied to the roll.

The slush pulp is fed through a hollow tube in the refiner, and passes in at the centre of the discs; it is then beaten by being carried round between the bars and grooves in the stationary and rotating discs. Centrifugal force and the pressure causes the pulp to be finally discharged at the periphery of the discs, and it falls through an opening in the bottom of the refiner.

Most of these refiners have a very big output, but this refiner does not, so far, seem to have been developed for use on rag papers, where probably much smaller units would be more convenient. This is a pity, as it seems likely that this type of refiner should be very useful in dealing with rag furnishes where wetting is required, but where it is not desirable to cut the fibres into shorter lengths.

It is claimed that there are very great savings in power by the use of the Sutherland Refiner as compared with the combination of beaters and jordans, and it has, of course, the advantage that the process is continuous.



[*Sutherland Refiner Corporation, Trenton, N.J.*

FIG. 65.—THE SUTHERLAND REFINER, DISC TYPE

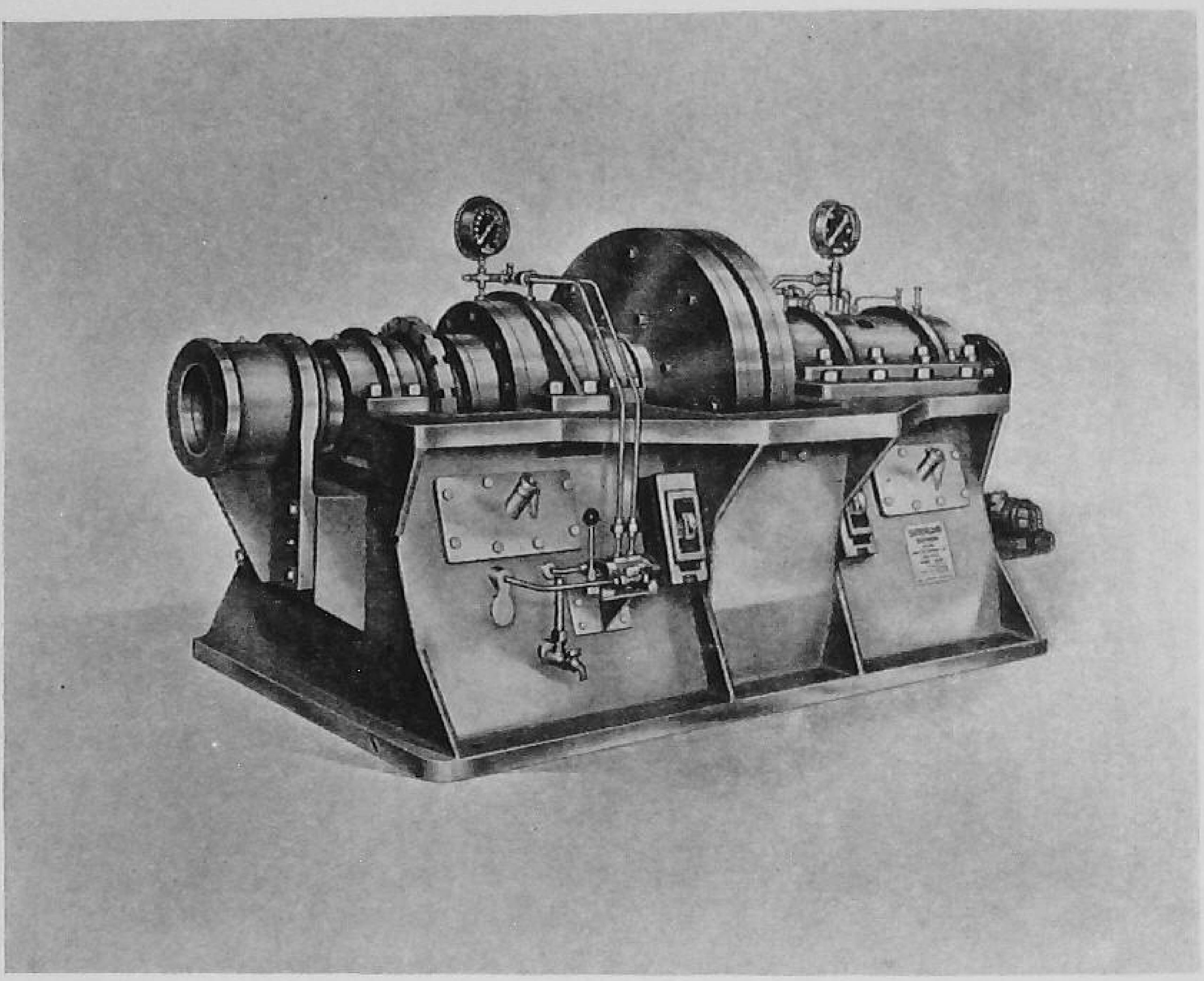
The state of the discs can easily be seen by opening the inspection doors, and it is possible to separate the discs about 2 in. to 3 in. for examination. If it is necessary to fit new discs, the old discs can be lifted out and new ones installed in two or three hours or even less. The grooving can be re-cut many times, and thus the long operation of rebarring is obviated.

Operating Principles of the Sutherland

In many mills one or several Sutherlands are the only piece of stock-preparation equipment to be found between the pulp supply and the paper-machine; in non-integrated mills, which operate on airdry imported or domestic pulp, a breaker beater or pulper may be used before the Sutherland to slush the stock to the required consistency of 3 to 5 per cent, or a jordan behind the Sutherland to shorten the fibre, if necessary.

The raw pulp enters under controlled pressure through the hollow shaft

of the stationary head (Fig. 66); the pressure pushes the rotating disc back to a predetermined distance, controlled by a hydraulic cylinder and thus



[*Sutherland Refiner Corporation, Trenton, N.J.*

FIG. 66.—THE SUTHERLAND REFINER WITH COVER REMOVED

The stock enters through the shaft on left and is discharged from the periphery of the discs shown in the centre.

creates the space between the two discs, in which the pulp travels to the orifices at the periphery. The grooves and bars in the discs and the rotation slow down the outward movement of the pulp and provide the beating, brushing, hydrating, combing and fibrillating which constitute the refining action. The higher the inlet pressure, the farther back yields the rotating disc, the larger becomes the distance between the discs and the faster travels the pulp. By the same token a low inlet pressure keeps the discs closely together, slows down the speed of the pulp on its way to the rim, so that it is being kept longer between the interacting bars and grooves and thus receives a longer and stronger treatment. In other words: high inlet pressure prepares a free stock, low pressure makes the stock slow, or wet.

Practically every required refining action can be obtained by adjusting and controlling the inlet pressure. Generally speaking the inlet pressure on free pulps is between 15 and 20 lb. per square inch and varies on slow stock

from 6 to 10 lb. per square inch and within these limits the required freeness can be attained with a very close tolerance.

[Sutherland Refiner Corporation, Trenton, N.J.

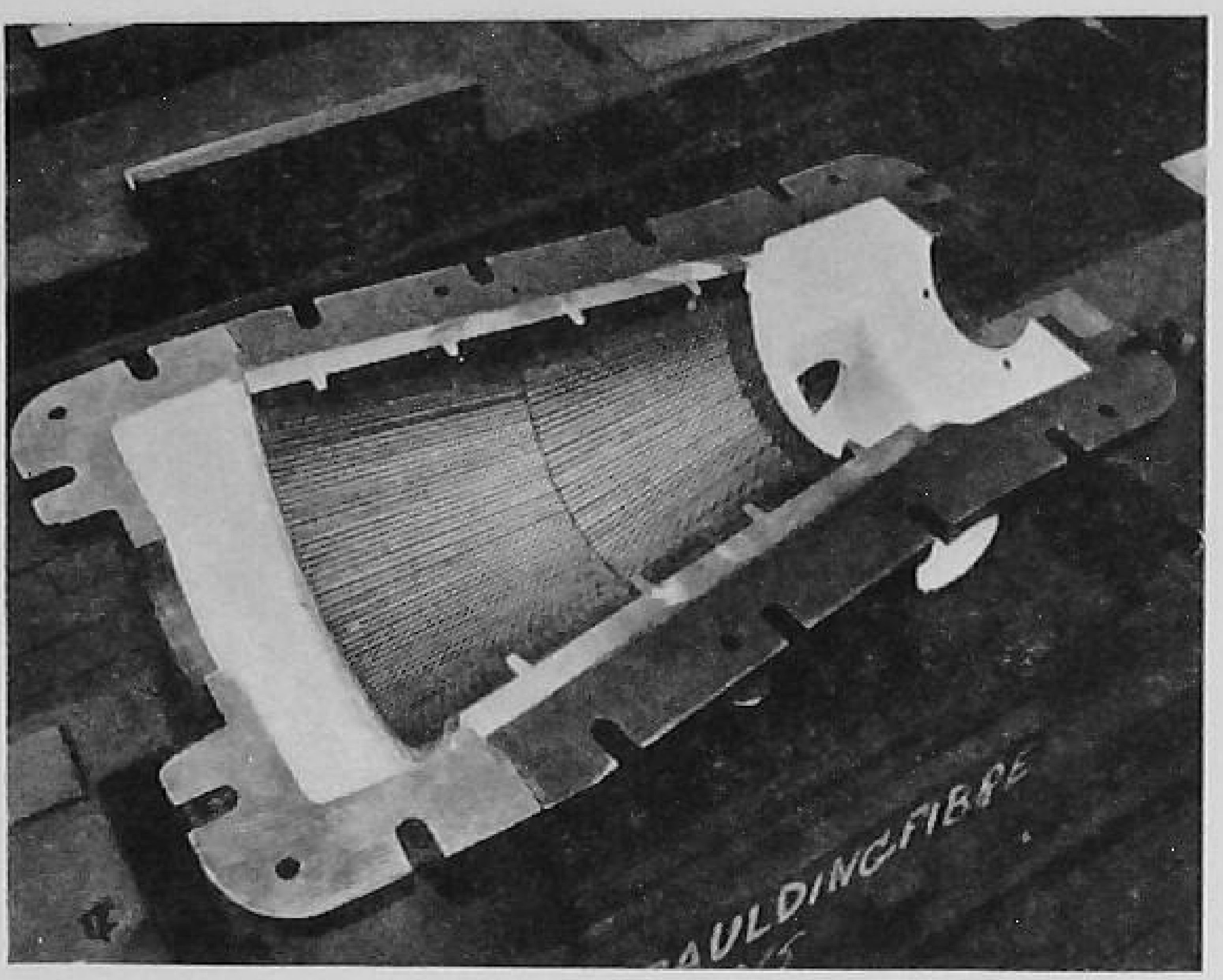
FIG. 67.—LARGE BATTERY OF SUTHERLAND REFINERS WITH DIRECT COUPLED MOTORS

The Sutherland Refiner is in principle a continuous single pass refiner; that is, the whole procedure of beating and refining is performed continuously in one single pass of the pulp from the centre inlet to the orifices at the periphery of the discs. However, in order to provide for a sufficient flow of stock at all times and to compensate for increased requirements of refined pulp at a higher machine speed, without exposing the stock to the hazards of agitation in a large machine chest, the refiner is designed to produce approximately 15 per cent more stock than the average consumption of the paper-machine and to recirculate this excess in a second pass.

The discs are set once in a position commensurate to the coarseness of the type of pulp and firmly locked in that position. From then on the required degree of refining is solely adjusted and controlled by the inlet pressure and a change in disc setting is neither necessary nor advisable. Discs can be inspected or changed without disturbing other parts of the refiner.

Hot Stock Refining.—Hot pulp coming straight from the digester contains many fibre particles, which in the conventional process of pulpmaking are hardening, when they cool off and must be discarded as screenings, but which can be turned into perfectly usable stock, if the pulp is treated in a specially designed Sutherland Hot Stock Refiner. Practical mill experience

has proved that these undissolved fibre bundles can be salvaged and that the yield from average pulpwood can be increased by 20 per cent over the conventional methods, by Sutherland Hot Stock Refining and several units of this type are in operation.



[E. D. Jones & Sons Co., Pittsfield, Mass.

FIG. 68.—SHELL OF JONES HIGH SPEED REFINER SHOWING ARRANGEMENT OF BARS

Successful commercial tests have been conducted in the refining of hot groundwood and sulphite pulp.

For some years now the practice has been growing of installing very small but very high-speed refiners in the machine house, entirely under the control of the machineman, for putting the finishing touches to paper stock. This method of dealing with stock at the last moment, just before it goes on to the machine, has a marked effect on sheet appearance. These small refiners revolve as a rule at far greater speeds than the big jordans, and as a result the stuff passes very quickly through them.

When the furnish is of wood pulp they may revolve at as high a speed as 1,400 revolutions per minute, and give excellent results, but when they are used on rag stock a much slower speed is advised to get the best result.

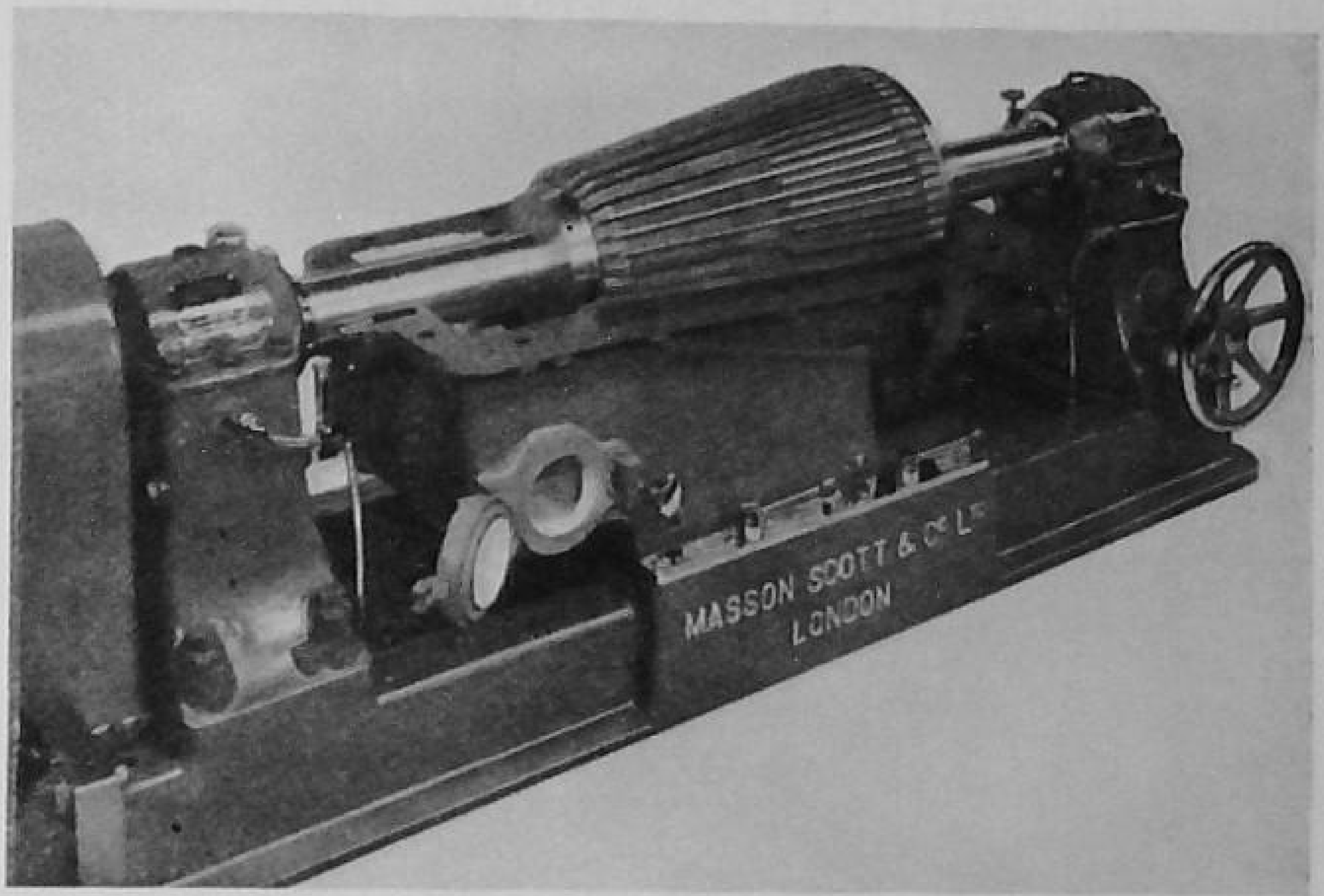
There are a large number of these little refiners in use nowadays, both in America where they originated, and also in England; and very fine results are claimed for stocks which are treated in this way, especially if the stuff passes almost immediately on to the paper-machine (Figs. 68 and 69).

The fibres are separated out into a very much better and clearer sheet, and a much more distinct watermark can be obtained.

It is usual to have these little refiners filled with stainless steel bars, both in the plug and also in the shell, and to pass the stock through at about 2 per cent consistency. The power consumed by these small refiners is quite high, but they deal with a very large amount of stuff in a very short time. For small paper-machines it will usually be found sufficient to install one of these, but on larger machines batteries of two or even three will be found to be more satisfactory, and will avoid the trouble of trying to force too much stock through them. Also, they may be used in series: where two are

installed the stuff passing through one and directly into the other, and then through to the paper-machine.

Mention has also been made elsewhere of using these small refiners for taking the bleed-off from the main strainers where this consists chiefly of knots and lumps of fibre, and treating it in a high-speed refiner and thus allowing it back into the chest, or back into the circuit again, and so saving what used to be thrown away as useless knots and lumps of fibre.



[*Masson, Scott & Co. Ltd.*

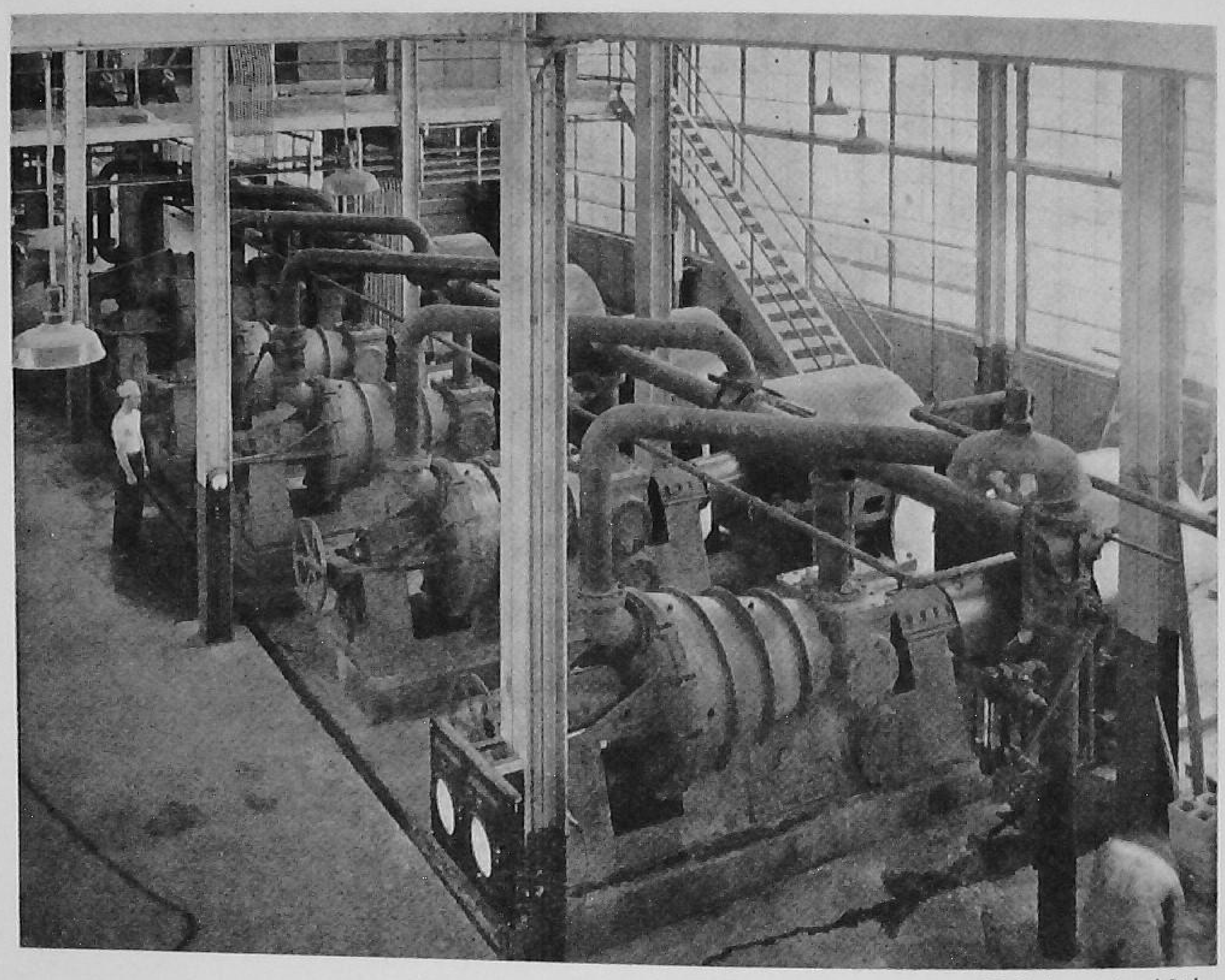
Fig. 69.—Small High Speed Refiner with cover removed, showing Plug in position and emptying Door for Junk

Grinding Refiners

Every refiner, after filling, should be ground in before it is put into use, and there are several reasons for this. First, the shell bars are bent or 'elbowed' to prevent their interlocking with the straight plug bars. When placed in the conical bore of the shell casing, these bars have a three-point contact: one at each end of the bar and another at the elbow in the middle. Between these points of contact there is a small space along the back of the bar and the shell, and there is a corresponding amount of metal at the top of the bars which must be removed to produce a true conical surface. Another reason for grinding is that in any assembly involving many separate parts, such as bars and woods, it is a mechanical impossibility to get the required accuracy to produce two conical and concentric surfaces. Even if this were possible in the first instance, the normal swell of the wood filling during soaking tends to distort the bars so that the shell must be ground to the plug.

The manufacturers of beaters and refiners grind the contact surfaces of bars true, in specially made grinders, but very few paper-mills are equipped to do their own grinding in this manner. It therefore becomes necessary for the mill itself to be in a position to grind in sand. The first thing that should be done is to soak the wood filling and give it plenty of time to swell,

and the refiner should, therefore, be entirely filled with water, and be allowed to stand for at least 24 hours. If all this time cannot be spared, then



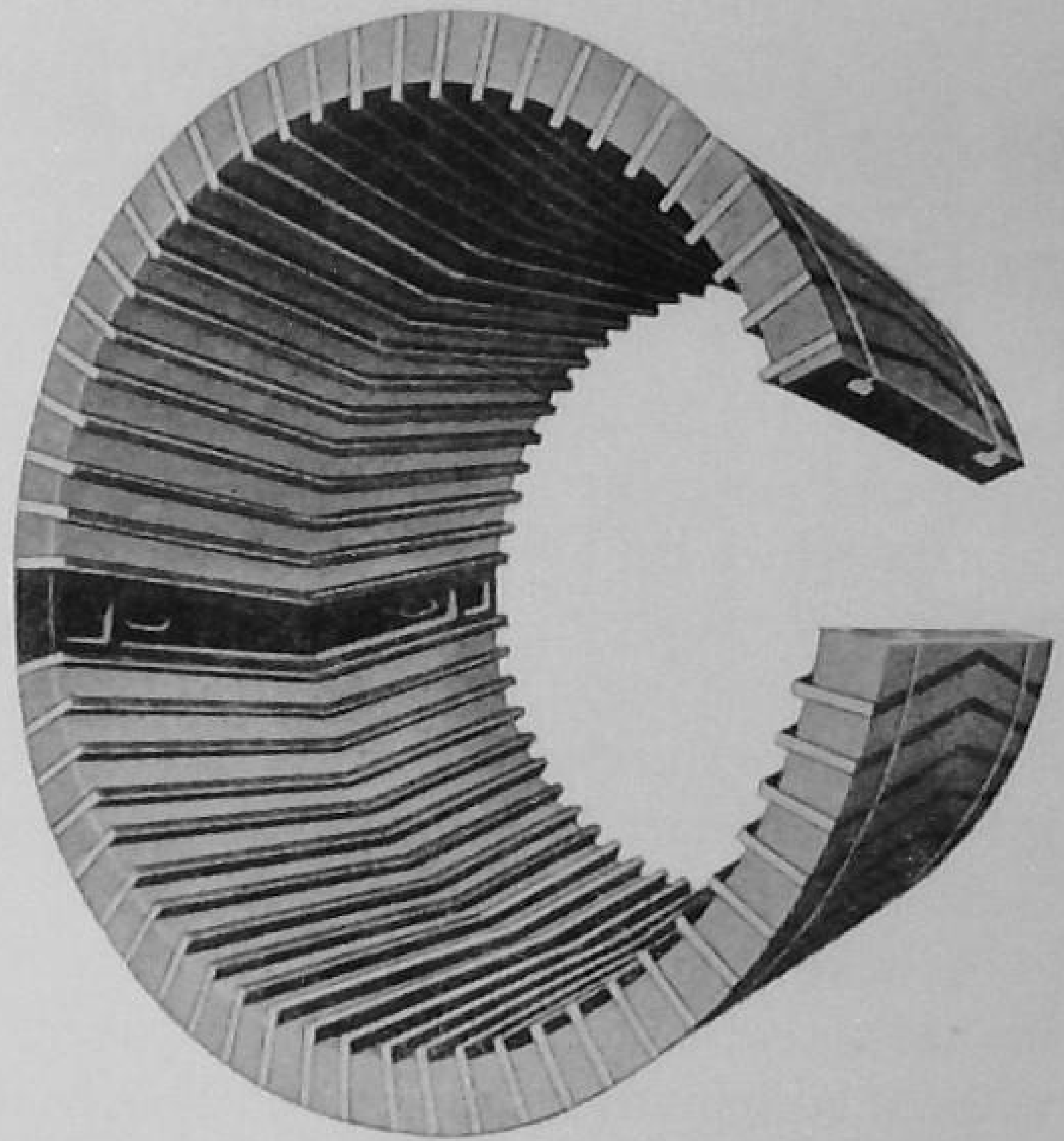
[B.C. International Ltd.

FIG. 69A.—BATTERY OF MIAMI REFINERS

warm water should be used, but this is not the best practice. Before putting in the water, the plug should be screwed up tight into the shell, so that there is no chance of the shell filling lifting due to the force of the swelling woods. Provide plenty of good sharp sand which has been through a screen of about $\frac{1}{8}$ inch to $\frac{3}{16}$ inch mesh. Quartz sand is the best, if it can be obtained, or any good clean sand such as is used for concrete work will do. If the refiner has a hole cover with a plate, on the side of the small end of the shell, this plate should be removed. If, however, there is no such shell opening, entrance has to be gained through the stock inlet. Insert a hose-pipe for furnishing the water; this pipe should have a control valve so that the quantity of water can be regulated. At the large end fix a discharge connexion. This should be a valve in one of the side or bottom cover plates,

and the one at the bottom is best. Some refiners have a threaded bottom plate purposely arranged for discharging the water.

Before starting to grind, back the plug away from the shell, and start the motor. Turn on the water at the small end and regulate the flow to about a full $\frac{3}{4}$ inch pipe without pressure. Adjust the discharge valve at the large end so as to maintain a constant level. This level should not be below the centre of the shaft, or overflow the handhole. With this amount of water there will be a vigorous circulation from the small end towards the large end, and back through the top half towards the small end. This will keep the sand agitated, and provides the necessary abrasive in suspension for grinding all parts of the filling.



[*Shartle Bros. Machine Co. Middletown, Ohio*

FIG. 69B—SHARTLE BROS. 'BULLDOG' REFINER FILLING

Now start to feed in the sand through the handhole at the small end with a scoop. Screw the plug in carefully until it just 'ticks' on the shell filling, and be careful to note the exact position, either by marking on the guides or noting the reading of the graduated scale. Work the plug gradually into contact with the shell until, from the sound, it is plain that the high spots are being ground off and better contact is being secured between the plug and shell bars. The job should not be hurried, and plenty of time should be given for the high spots to grind down. When this condition is apparent from the sound, feed the plug in a little more, all the time using plenty of sand. Watch the temperature of the out-flowing water, and do not let it rise above 120° F. If necessary, adjust the flow of water to keep the temperature within limits. It is important that overheating should not be allowed to occur, otherwise the plug or the shell may be distorted on cooling off, and the whole benefit of the grinding job will be lost.

In the case of a new refiner, or one in which the plug has been filled and ground by the makers, a total movement of about $\frac{5}{8}$ inch should be enough to ensure full contact between plug and shell bars. In the case of a

refiner refilled in the mill, without any grinding facilities, grinding in sand will probably require a movement of $\frac{7}{8}$ inch to 1 inch to get the desired results; and in the latter case greater care will have to be exercised during the first part of the grinding to work out the high spots without doing damage. One to 3 hours should be sufficient for a newly-ground refiner, but for one which has been refilled at the mill it may take 4 hours or more.

After the operation is finished, take the old covers off and wash out all the sand. It is particularly necessary to wash clean any sediment in the bottom of the shell filling and in the bottom of the large head and the throat at the small end of the shell. Remove the packing, and wash out all the sand which has lodged in the stuffing boxes. It is a good thing to use old packing for grinding, and then to repack with new packing before putting the refiner into use.

The latest development in beating brings us back to the ordinary beater. It is revolutionary in its technique and the saving it offers in power; and it is claimed that it gives a high degree of efficiency.

It takes the form of a beater-cover which, when fitted to any beater, immediately enables the beater to do three times the work in preparing the stock without taking any more power. This enables a mill to dispense with the use of three beaters out of five, and thus gives about 60 per cent saving in power.

It is not possible at present to give details of the construction, or indeed a complete description of the action of this cover. It is claimed, however, that after four months of completely satisfactory trial, working day and night, one beater has continuously done the work of three, and on occasion—and for long runs—the work of four beaters, with complete satisfaction, on papers made from the hardest sulphite and sulphate pulps. Trials have also been made on flax, which reached a very high degree of wetness in a quarter of the time taken in a beater with the ordinary cover.

It is claimed that any furnish can be beaten in one circulation of the stuff round the engine.

The principle of the cover is to retain the pulp between the roll and the cover for a predetermined length of time without allowing it to circulate round the trough except at predetermined intervals.

This cover has been patented by Mr. Robert McNeill, and is made by Joseph Winterburn Limited, of Bury.

From its performance, this beater-cover seems as if it may be restoring the beater again to the impregnable position it has held in paper-mills for very many years, a position which has recently been strongly challenged by the refiner in various forms.

(*Note.*—We are indebted to Messrs. E. D. Jones for the above description of refiner grinding.)

CHAPTER X

BEATING OF VARIOUS FIBRES AND THE CHARACTERISTICS THEY IMPART TO PAPER

Cotton—Flax—Wood Pulp—Esparto

Cotton.—Cotton may be used to produce a great variety of papers. In practice the use of new cotton fibres is limited to the making of high-class papers, on account of the high cost of the raw material, and the power and labour consumed in beating, making, tub-sizing and finishing. This fibre is supreme for very strong loan, ledger paper, thin banks and the best qualities of writing and drawing papers.

The most durable, though perhaps not the most absorbent blottings are made from new cottons. The degree of fibrillation given to these papers varies to extreme limits. Thus, for a strong loan of the substance of Large Post 21 lb., from 6 to 8 hours' beating may be required, while a very close and clearly water-marked writing paper of the same substance and quality will take from 2 to 4 hours.

Since in most 'fine' mills both of these papers will have to be produced by the same beating engines, it is a matter of the highest skill to manipulate the rolls to fibrillate the loan properly if the tackle is moderately sharp. On the other hand, the cutting rather than fibrillating of the fibres, for the writing paper, would be much easier to accomplish. If the tackle is dull and blunt, the difficulty would be to get the fibres for the writing paper cut fine enough without too much fibrillation taking place. Again, the plates and bars wear down and become dull as time goes on, and this renders all records of roll pressure useless, since the conditions are constantly changing. Thus we are left, in the long run, dependent on the skill of the beaterman who knows the conditions and beats according to his judgment. Therefore, though statements of beating time might conceivably be given for different weights and qualities of paper, they would be correct only in a very general sense, and only in that sense can they be given. For instance, if the paper we are considering (a strong loan) were being dealt with by four beaters, of which one had a fresh and consequently sharp plate, the beaterman could not by any possible manipulation of that beater give the stuff in it the same fibrillation as in the others in the same time. It is doubtful whether by having less pressure on the plate and giving the stock longer time he could ever accomplish it.

Besides the condition of the tackle and the beating pressure, the concentration of the stuff makes a very great difference to the result. The strong loan and the fine writing paper may again be instanced. In a beater nominally of 400 lb. capacity, the quantity of the former may be as much as 4 cwt., and of the latter not more than 3 cwt. The writing paper will not have the strength of the loan, but this is not expected, or required, the main consideration being a close and clearly water-marked sheet. The lower the concentration of stuff in the beater the more chance it has of being cut, owing to the fibres passing through between the bars and plates in a thin stream, instead of a thick layer. An exactly similar effect is seen when finishing a thin paper on the calenders. When putting through a thicker substance with the same weight of rolls, the finish is not so high. The thinner paper has fewer fibres in its bulk to form a cushion, and therefore each individual fibre has the weight more directly applied to it.

Again, by the higher concentration of stuff, the fibres are subjected to more pressure and rubbing on each other and against the sides and bottom of the beater, which helps to roughen the surface of the fibres and separate the fibrillæ that have been opened up by the roll. Also, the head of stuff in front of the roll is subjected to a battering effect by the roll bars, which is absent when the stuff is rushing through, suspended in water. Between the plate and the outlet of the backfall, a good deal of pressure and rubbing takes place.

Although we have taken cotton fibres as an example, these remarks are applicable to all kinds of fibres. Cotton fibres, especially those from new cotton cuttings or rags that have not been subjected to frequent washing and bleaching, are very opaque and bulky. Even when well fibrillated, as in a thin bank, this is apparent. As we have shown previously, the cotton fibre has a peculiarity which is of the highest value in giving the qualities of strength, bulk and opacity. This is its twisted form, which even after drastic treatment in the beater is seldom entirely lost. As an illustration of these qualities combined, let us take a ledger paper of a substance equal to about 27 lb. Large Post, with a water-mark. The beating time would be about 4 to 5 hours, and our beater would be filled to about 3½ cwt. of stuff. We would then expect to find that the stuff would be rather wet on the machine, but the fibres would be fairly long, or at least a good proportion of them. If some of these long fibres are examined under the microscope most of them would be readily recognized as cotton by their more or less twisted form. These are the fibres that have escaped being much cut or fibrillated during their time in the beater, and they form the backbone or framework of the sheet. While they are firmly bound together by the fibrillæ, they serve to

prevent the close packing of a more highly fibrillated paper. At the same time the wetness or fibrillation of the other fibres allows the dandy roll to make a good impression. Thus we have the natural strength, bulk and opacity of the long fibres, and the felting strength and clear water-mark given by the fibrillæ.

While we have this illustration before us, we may just touch on a point in beating which seems to have been overlooked by many so-called beating experts, who seem to consider that the perfection of beating is to have the fibres of a uniform length. This is true only so far as the beating for printing, litho and such-like papers is concerned. But the ideal ledger paper, and indeed many other papers, cannot be properly made by fibres beaten to a uniform length. This is one of the factors that have kept the hollander beater in the highest place as an efficient beating engine. Its irregular and unequal circulation, even in the best designs, ensures that many fibres are little touched, while others may be driven through the nip many times.

Unless there were a fair proportion of long fibres to form the framework of the sheet, there would not be much strength and bulk, and without the fine fibrillæ there would be poor water-marking and felting.

Reverting, however, to our writing-paper example, uniform length of stuff is of more advantage, because strength may be considered of secondary importance. The fibres being *cut* to produce fine stuff still retain their original characteristics, opacity and bulk. The quicker circulation of the less concentrated and lighter-charged beater will ensure that fewer fibres escape being cut. Cotton beaten quickly—that is, cut fine—carries the water well up to the dandy roll owing to the close packing of the fibres. The roll makes a good impression because there are fewer long fibres to prevent the sinking in of the protruding letters or designs. After passing the dandy roll, however, the suction boxes are seen to take the water out of the sheet very easily, showing that little fibrillation has taken place in the beater.

If, however, we intend to make our writing paper of thinner substance, say 18 lb. Large Post, we have to alter our beating a little. We must fill in more stock and allow a little more time to beat, so that we may have some long fibres and more fibrillæ, to help to run the paper over the machine, without having breaks and 'pick ups' at the dandy roll. We can do this because the thinner substance allows and requires more water to be used on the machine to close up the sheet, and the impressions of the dandy roll are more transparent. From this a step further, higher concentration of stuff and still longer time beating, give us stock suitable for a bank paper of 15 lb. Large Post, and so on down to thin banks of 11 lb. and under.

Reversing the process, as we increase the substance of our paper to, say,

a ledger paper of 72 lb. Imperial, we have to beat with less fibrillation. This is not because we do not require strength, but because we find it very difficult to get the water out of the fibrillated stuff when we run it over the wire. Therefore the beating is required to be a very skilful compromise between cutting and fibrillating the fibres. We must not cut them too short or strength will be badly down; we cannot leave them long and raw or we will have trouble in getting them through the strainer plates and get a poor water-mark. In general, with a fair quality of cotton fibres, if we treat them as for a ledger paper of about 30 lb. in Large Post, by heating the stuff to about 90° to 95° F. on the machine, a successful result will be achieved.

With substances heavier than this, strength has to be proportionally sacrificed to the capacity of the machine to extract water, and the fineness of the strainer slits. A good cotton furnish beaten for 1 hour with sharp plates may be run up to 150 lb. Imperial on a 40-foot wire of 66 mesh at 15 to 20 feet per minute without heating at the machine. Heating up to 90° to 100° F. allows the stuff to be put down with a little more length, as more water can be used to run it through the strainers.

When dealing with cotton fibres from old rags, more gentle treatment is necessary. Fibres that have been subjected to prolonged wear and repeated washing and bleaching before coming to the mill, and then to a fairly drastic treatment there, have lost a great deal of their stability and bulk, and—worse still—have become partly oxidized. Fewer twisted fibres are seen, and the most careful beating cannot make up for the loss of their original strength. They are also frayed and bruised (that is, fibrillated), and therefore work wetter on the machine. They serve to make rag papers that may be sold comparatively cheaply and fulfil a more modest standard of quality, and they form the basis of the great majority of writing and ledger papers.

Old soft rags, suitably treated and beaten with very sharp roll bars and plates, make the softest and most absorbent blottings. The beating time is from ½ to 3 hours, according to substance. Blotting Demy (17½ × 22) varies from 18 to 120 lb.

Owing to its absorbency and the purity of its fibres, cotton takes most dyes very readily and produces very brilliant shades.

Cotton fibres blend extremely well with the fibres of chemical wood, and very beautiful and useful papers of all types, from the thinnest banks to the thickest chromos, may be made from a mixture of the two.

The strongest form of cotton rag is that known as 'new unbleached calico cuttings' from cloth which has been woven from Egyptian cotton. The half stuff from this material bleaches up to a beautiful snowy white and may be beaten to yield very strong papers of all substances.

In general, papers made from cotton fibres are more bulky, and handle better than those made from any other fibre, or mixture of fibres, and it is this quality which renders them very valuable, and in fact indispensable, for papers which are required to bulk well.

Flax or Linen and Hemp.—The value of the linen fibre to the paper-maker lies in its great capacity for fibrillation. Its thick walls are fundamentally striated and its canal is small in comparison with its bulk. Obviously it will require heavy beating to disintegrate it. Unless the bars and plates are very sharp it splits more readily than it cuts. For this reason, compared to cotton, its use is rather limited except for special papers. It is seldom, if ever, run as a whole furnish, but it gives, even in a small proportion, a certain 'feel' to paper which can be readily distinguished by a skilled paper-maker. This feel is very difficult to describe, but may be attributed to the cool, glossy surface of the fibre.

It does not readily take a good water-mark unless highly fibrillated, but in the latter case the binding effect of its fibrillæ gives great strength and hardness. For a good ledger paper, up to 25 per cent may be used with advantage. It must be beaten separately, and not in a beater with the other components of the furnish, as the heavy treatment it requires would destroy the strength of these components to a greater extent than the linen could compensate. Perhaps neglect of this very obvious precaution is the reason why many paper-makers assert that linen has less strength as a paper-making material than cotton.

A blend of chemical wood with 10 per cent of linen gives a paper of surprisingly good strength and hardness, and—judging from the frequency of this combination in many papers we have examined—it is a very popular one.

Although an all-linen paper is very seldom met with, in thin papers the proportion of linen may be greatly increased with excellent results. With about 8 to 12 hours' beating with dull tackle and high concentration of stuff in the beater, a furnish of 75 per cent linen will produce a pulp that will work extremely wet on a 66-mesh wire at 7 lb. in Large Post and give a very strong paper.

The hardness of the linen fibre renders it more immune from serious damage in the beater than is the case with cotton; for while a careless manipulation of the roll during the first hour or two in the beater will ruin a furnish of cotton, the linen seems capable of standing the weight of the roll better, and is not so likely to be spoilt unless all the tackle is very sharp.

There are various reasons for the linen fibre being more easily fibrillated in the beater than cotton. In the first place, as we have already said, the

structure of the fibre lends itself to longitudinal splitting, and in addition the fibre contains knots or bulbous swellings which split and become fibrillated by the weight of the roll.

There is, however, another reason which accounts in no small measure for the easy fibrillation; it is, in fact, that the linen cloth, in the case of new cuttings or used rags, has had much more hard usage during its existence prior to its arrival at the mill.

The linen fibre, being itself hard and harsh, produces a correspondingly hard thread and cloth. This cloth is so harsh and lacking in suppleness that it is unsuitable for clothing or household use until it has been softened and made pliable by the linen cloth manufacturer. To effect this softening the cloth is beaten, or 'beetled', as it is called, by wooden beetles, or clubs, so that someone else has a hand in the fibrillation of the stuff before it is put to its various domestic uses. Again, linen being hard wearing, it lasts many years in the form of sheets, tablecloths, etc., and in consequence it is laundered many times more than a similar article of cotton.

All these things help in the preparation of the rags for the beater, so that by the time the linen stock has been broken into half stuff in the beater, it is already well fibrillated and feels wet and greasy to the touch.

The amount of linen which can be used in the furnish is really limited by the length of the machine wire and the efficiency of the suction boxes; for if, with 25 per cent of linen, the paper can just be couched without crushing, it is no use to bring up the proportion of linen to 35 or 40 per cent. This will only give the machinemen endless trouble trying to get the water out, and the appearance of the sheet will be spoilt without any appreciable gain in the ultimate strength of the paper.

In general, if linen is to be used, it will be found advantageous not to use too much, but to get full value from a moderate amount by carefully beating it with blunt tackle, and so defibring it that it will entwine and bind together the rest of the furnish and give that characteristic hardness to the finished sheet.

When the furnish is to be 25 per cent of linen and 75 per cent of other fibres, beaten separately in four engines, it will generally be found best to furnish the linen first and leave the other fibres till last, as it will be the last to reach a satisfactory state of fibrillation, providing that the tackle in all beaters is in the same state.

Never beat a mixed furnish of cotton and linen in the same beater if it can possibly be avoided, for, unless the amount of linen is small, the amount of roll required to beat it will destroy the cotton, and the result will be worse than if no linen had been used.

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Linen fibres or, as they are more usually called, flax fibres, make an ideal furnish for thin tissues. They may be used entirely alone for thin banks, air mail papers, carbons or cigarette papers. The reason they are referred to as flax when used for tissues is because they are generally used in the form of raw unused fibres, which have in fact not been woven into linen textiles.

They are generally bought by paper-mills in the form of flax wastes and tows from the flax factories, where they are rejected as unfit for spinning. These raw flax fibres need severe treatment in the boiling and bleaching processes to render them white and clean, as they have usually not been retted or carded, and are therefore heavily coated with shive, which is the woody or ligneous core of the flax straw.

Actually attempts have been made to use the raw flax straw from linseed growers in some paper-mills, but generally they have not succeeded in making very satisfactory pulps from flax in this form, owing to the difficulty of getting rid of the shive. Flax wastes generally, however, are excellent materials for making strong and opaque tissues of very good white colour.

Hemp is used by paper-makers in the form of hemp ropes, nets, string and the raw fibre. It is generally used only for making very thin opaque papers of great strength, and it has no equal for this purpose. Formerly very large quantities of hemp ropes were available from ships and these, being impregnated with tar, were difficult to bleach to a good white colour. Nevertheless, very good white pulps can be made from tarred hemp ropes, after prolonged boiling and bleaching. The pulp is soft and silky and makes beautiful thin papers of very widely differing types, depending on the treatment of the fibres during boiling and bleaching, and especially on their treatment in the beater. Very opaque papers may be made if the hemp pulp is made to work free, a typical example being thin India Bible paper. On the other hand, the finest condenser tissues are made from hemp, and when calendered they are quite transparent. In the latter case the pulp is subjected to very prolonged beating with dull tackle.

Besides hemps, which have been used previously in the form of ropes and nets, raw hemp fibres are used for some types of thin tissue papers. The sources of hemp are Russia, Italy and India, where several different types are grown. Generally the hemps grown in the East are coarser and more harsh than those grown in the West, and the rope and strings made from them are harder and stiffer. The same may also be said of the papers made from celluloses of these different hemps.

Wood Pulp.—So far we have been dealing with materials that require heavy beating or cutting. That is to say, a great deal of power is consumed

by the beating engine, in the one case for fibrillating and in the other for cutting fibres.

Wood pulp fibres are short enough in themselves to need little cutting, and they have not the structure or stability to produce extensive fibrillation. This brings us to the obvious conclusion that it is possible to find beaters more economical than the hollander for the treatment of wood fibres. Not that any improvement in the quality of the paper made from wood pulp in a hollander can be looked for by using any other type, but because it is uneconomical to have to drive a heavy roll, whose weight is never fully used, and because of the slow and uncertain circulation of the hollander.

The beating of wood fibres is confined in a very great measure to clearing fibre clusters and 'brushing' the fibres so that they are roughened by the partial fibrillation of their surfaces.

This suggests a type of beater with a lighter roll and quicker and more perfect circulation than the hollander. Many good beaters of this lighter type are now in use, such as the Taylor and Tower beaters, which have separate circulators and light rolls, and are found to be perfectly efficient in beating wood, esparto and straw.

Many qualities of chemical wood pulp show a surprising degree of fibrillation when examined under the microscope, after careful beating, and run well on the machine. They are suitable for the cheaper kinds of typewriting papers, and down to 15 lb. in Large Post will take nice water-marking. Under that substance it is difficult to water-mark an all-wood furnish without a great deal of trouble with dandy 'pick-ups', but very thin papers may be made with a plain wove dandy roll. The reason for the trouble with dandy picks is the shortness of the fibre. Certain qualities of wood pulp are, however, now available which take a good deal of beating and produce long, wet stuff.

Wood pulp produced by the soda or sulphate processes has better bulking qualities than sulphite pulp, but tends to be too free and raw for these papers.

Under the beating of wood pulp comes the important operation of treating newsprint stock and stuff for cheap printings and supercalendered papers. In these cases we have the best examples of 'free beating' as opposed to the beating of cotton and linen for the manufacture of writing papers.

The beating of newsprint is usually divided into two operations; the first consists of soaking and mixing the strong sulphite and mechanical pulps in a large hollander type engine, which has a roll with single and equidistant bars, as opposed to the usual clumps of three or four bars. The sulphite is furnished first and then the moist mechanical and broke, or the broke may be mixed up in a separate engine. The chief requirements are maximum speed in

furnishing and the elimination of wire bands and bits of wood from the bale wrappings, as these are liable to do damage later when the stuff is passing through the refiners.

To save time in furnishing the engine all the bales of pulp required should be stacked close round the beater, or on a wooden stage at the edge, and before the previous lot of stuff has been emptied the hoops should be removed and taken away. As soon as the stuff is let down the white water is turned on and the pulp thrown in—so many bales of sulphite followed by the required amount of mechanical. The proportion is usually in the neighbourhood of 20 per cent sulphite to 80 per cent mechanical.

As soon as the pulp is properly broken up and mixed, say in about 1 hour, the valve is drawn and the stuff let down into the refiner chest. Here it is diluted to a consistency suitable for pumping through the refining engine. It is during its passage through the refiner that the beating (such as it is) and clearing of the stuff are effected, and the beaterman manipulates the disc of the refiner in the same way as the roll of the hollander is manipulated when beating cotton and linen rags.

The consistency of the stuff as it passes through the refiner is important, just as it was in the beater, and the more concentrated the stuff the more 'beating' will it get, and vice versa. It is usual to have two refiners coupled together, the stuff passing through the first and then straight through into the second and into the machine chests.

The chief requirement for the satisfactory production of newsprint stock is absolute uniformity hour by hour and day by day, so that the machine can be kept going at full speed for very long periods without breaks. Consistency regulators should always be fitted, in order to check and maintain the uniformity of the stuff.

Once the machine has started up and got into its stride it is up to the beaterman to keep his stuff absolutely regular and at a uniform degree of 'freeness', so that just sufficient water will be carried to enable the sheet to be put together and no more. Once the web reaches the suction boxes it must part readily with its water so that it may be easily couched.

The beaterman must see that his assistants use care in furnishing so that no pieces of wood or foreign matter get into the beater, as these things, when broken up by the refiner, pass into the web in the form of small splinters and shive, and cause breaks. Properly beaten with suitable tackle, sulphite wood pulp can be made to produce beautiful banks and bonds; and thin tissues, down to a substance of 5 lb. Double Crown, may also be made, their strength and toughness being comparable with tissues made from rags.

The production of these thin papers necessitates long and careful beating

and proper tackle; blunt bronze bars or, better still, stone rolls give the best results, as the original length of the fibre is preserved and the long-continued brushing out of the fibres gives the necessary fibrillation and subsequent wetness.

Esparto.—Esparto fibres are very fine and short; nevertheless they require a certain amount of beating. This amount depends on the quality of the grass and the treatment it has previously received. The fibres of Spanish grass are tougher than those of African, and will stand more beating, thus giving a stronger and harder paper. In order to eliminate shive, esparto fibres must be well brushed or rubbed, with as little cutting as possible. This must not be carried too far, as they are naturally slimy, and if the process is overdone small knots will form in the chests and strainers and the web will stick to the press rolls of the machine.

Sometimes a charge that has been overboiled or overbleached will defy the efforts of the beaterman to make it into a good running paper, and then the only remedy is to increase the proportion of wood pulp in the furnish. Esparto is not suited for running over the machine without a proportion of chemical wood fibres to form a base or framework for the paper.

As might be expected, esparto papers are very close and regular in composition and take a very clear water-mark. They take a very fine finish with light calendering, and give a more bulky paper than wood pulp with the same finish. Thus they are most suitable for fine printing papers.

Esparto is very absorbent and requires a great deal of resin size to make a hard-sized sheet. It produces an excellent tub-sized paper with a good hard rattle and more strength than might be expected. The uniform size of its fibres makes it very useful for the production of stamp and cheque papers, and such papers as must have a very accurate register of the water-mark; and the close even surface, which no other fibre can give, is very highly prized for fine lithographic work. Some of the 'imitation art' papers made in this country with a very large proportion of esparto are the finest papers in the world for magazine printing.

The question of the proportion of sulphite wood and esparto used in the furnish is often decided by the respective price of the two materials. It is in the beating of esparto papers that many experiments have been carried out with new and revolutionary designs in beating engines.

Some of these have been quite successful, notably the Taylor and Tower beaters, in which the stuff is circulated by a pump, up a pipe to the roll, which stands at the top (see Figs. 54 and 55, pp. 130 and 131). The main objects of these beaters are saving of floor space, quick circulation and a saving in power.

To get the best results from esparto the preliminary treatment must be regular, and beater tackle should be kept in a uniformly correct condition.

Wet-Strength Paper.—Many types of paper possess wet-strength properties in greater or less degree, but the term 'wet-strength paper' now refers more particularly to those made from pulp which has been treated with amino resins prior to formation on the paper machine, whereby the finished paper becomes resistant to disintegration when wet.

Amino resins for this purpose appear to have been first used in U.S.A. about 1942 and in Great Britain late in 1944. Owing to demands for maps and packaging materials to withstand war-time conditions, the manufacture of these papers developed rapidly.

The first amino resin which achieved conspicuous success was of the melamine formaldehyde type. In practice the dry resin is dissolved in dilute hydrochloric acid and allowed to age for some hours, during which colloidal particles of resin bearing a positive charge are formed. When added to paper-making stock the positively charged (cationic) particles are well retained by the negatively charged (anionic) cellulose. The wet-strength developed in the paper varies with the quantity of resin retained, and the extent to which it can be cured by adopting low pH values (4·2–5·0) and high cylinder temperatures (110°–130° C.), and by reeling while still hot. Since all kinds of paper-making fibres carry a negative charge when suspended in water, melamine resins bearing a positive charge are equally efficient for all grades of chemical pulp.

The urea formaldehyde resins at first available to the paper trade were either electrically neutral or electro-negative in character. Supplied in syrup form, they can be added directly to the stock. Curing conditions are similar to those necessary for melamine resins. For reasons which are not yet clear, they are fairly well retained by unbleached kraft and sulphite pulps, and continue to be used in the manufacture of such papers on account of their relative cheapness. These earlier types of urea resins are, however, retained only to a slight extent by fully bleached pulps.

Resin manufacturers have therefore recently produced modified urea formaldehyde resins which carry a positive charge. Such resins are usually retained equally well by both bleached and unbleached pulps (presumably by a mechanism similar to that described for melamine resin) and now compete with melamine in the commercial production of bleached wet-strength papers.

CHAPTER XI

REPULPING 'BROKE'—EFFECT OF ADDING BROKE TO THE FURNISH—BROKE AND WASTE

WASTE paper, properly treated, is an important and valuable raw material for the paper-maker, yet it would seem, from the inadequate space and appliances for dealing with the disintegration of broke which are found in most mills, that this department was seldom planned out at the beginning, but was added when the necessity was realized. Yet it is in this department that a great deal of money may be lost or saved. There are several methods of dealing with broke or waste paper so that it may be again used in the furnish. Wet doctor broke from press rolls may be carried to the beaters and packed in with the next charge. Broke that has been dried but not tub-sized is sometimes filled in and cleared with the other items of the furnish.

This, however, is a risky process, as even with the greatest skill and care it is often the case that uncleared bits get into the chests.

The method employed must be one that is best adapted for the particular qualities made, and will depend on whether waste paper brought from outside the mill is used. So we find that nearly all mills have their own methods, of which the following are typical:

1. Soaking in tanks.
2. Boiling or scalding (either in stationary or revolving boilers).
3. Breaking in potchers with hot water, followed by steeping in draining tanks.
4. Boiling, followed by breaking, in edge runners, kneaders or pulpers.
5. Breaking in pulping engines with steam or hot water, without preliminary treatment.
6. Hydrapulper.

From the above it will be seen that there are two essential requirements: (*a*) the soaking in water (generally hot) and (*b*) the mechanical action of defibring. To get good results these two must be combined in the process: (*a*) alone takes too long a time and too much space for tanks, with imperfectly soaked bits left to be dealt with by the beaters; (*b*) requires too much power without (*a*) and is useless for reducing hard-sized papers.

1. *Soaking in Tanks.*—This method is used mostly in mills making low-grade papers, such as middles or wrappers, where the presence of uncleared

bits is of little consequence. The paper, mostly waste paper of low quality, is put into tanks with water, the charge being pressed down with poles in order to save space. After soaking for one or two days the pulp is dug out and filled into the beaters.

2. *Boiling in Rotary Boilers.*—The two essentials are combined by this process, but the disintegration is not complete unless after prolonged treatment. Paper that has been boiled is reduced in 'quality'; if the boilers revolve at a sufficiently high speed—3 revolutions per minute—excellent disintegration is obtained. If too much water is used, size is boiled out and is lost, and the strength of the fibres is very much lessened.

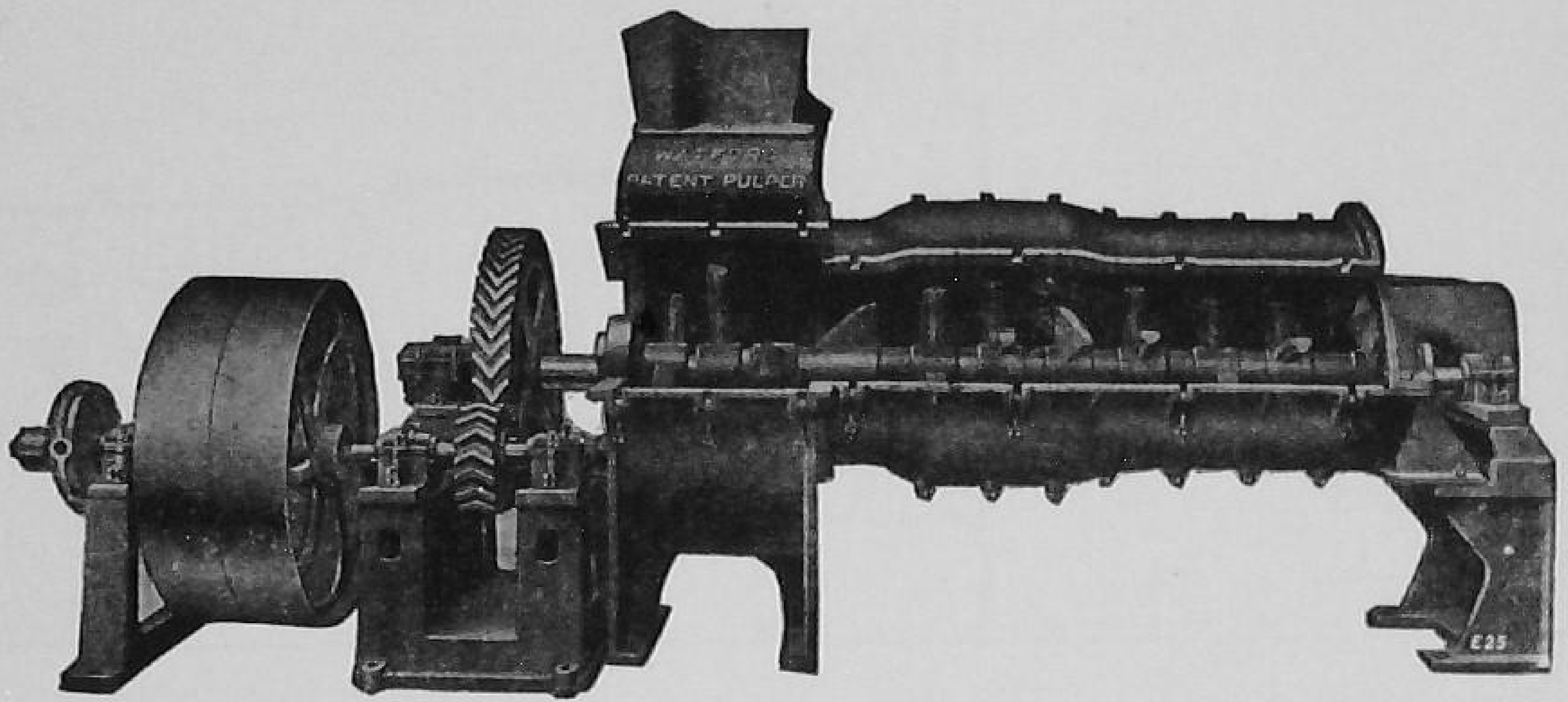
For this reason, many paper-makers prefer to defibre the broke by means of a kollergang or kneader, after a light boil in either a stationary or rotary boiler.

3. *Breaking in Potchers followed by Steeping in Draining Tanks.*—An old hollander beater is generally used. The broke is filled in with water and heated by blowing in steam to nearly boiling point. After the potcher has been fully charged the broke is roughly broken for a short time and then run into draining tanks. When the water is drained away, the pulp is dug out for the beaters. This is a very expensive way of treating broke, owing to the power required to break the paper and the steam used to heat the contents of the potcher.

4. *Breaking in Special Pulping Engines with Steam or Hot Water, without Preliminary Treatment.*—This is the best and cheapest method and is now being used by all up-do-date mills. Among pulpers one of the most popular is the Watford Patent Pulper (Fig. 70). This machine consists of a cast-iron shell within which is a revolving shaft, on which is fitted a series of curved iron teeth or arms. The inside of the shell is also studded with shorter teeth, between which the revolving arms turn. At the smaller end is a hopper into which the broke is fed together with a supply of hot water for hard papers or cold for softer stuff. At this end the teeth are short and stout, gradually increasing in length so that the pulp travels towards the other end as it is broken up, the longer ones having the more disintegrated pulp to work through. The revolving shaft and teeth have a speed of 50 to 60 revolutions per minute and form a sort of screw, which gradually draws the stuff to the discharge opening. The conical casting is in two parts, of which the top half is hinged for obtaining access to the interior. The action is continuous, but may be made intermittent if desired by closing the discharge doors. The output is from 6 to 20 cwt. per hour, according to the size of the pulper and the quality of the broke. The power required is from 15 to 36 h.p. Hot or cold water or steam may be used while feeding in the stock,

but only soft papers can be properly pulped without heat. No colour, size, loading or fine fibres are lost by this method of pulping.

Some pulpers are still in use which work with intermittent charges.



[*Watford Engineering Works Ltd.*

FIG. 70.—WATFORD PATENT PULPER

These are similar in construction to the dough mixers which are used in bakeries. They consist of metal troughs in which revolve two curved arms with serrated edges. The trough is gradually filled with the stock and a supply of hot water. The broke is usually disintegrated by the time the pulper is fully loaded, which is a slow process; when ready, the whole vat is tilted with the help of heavy counterweights, and emptied into trucks.

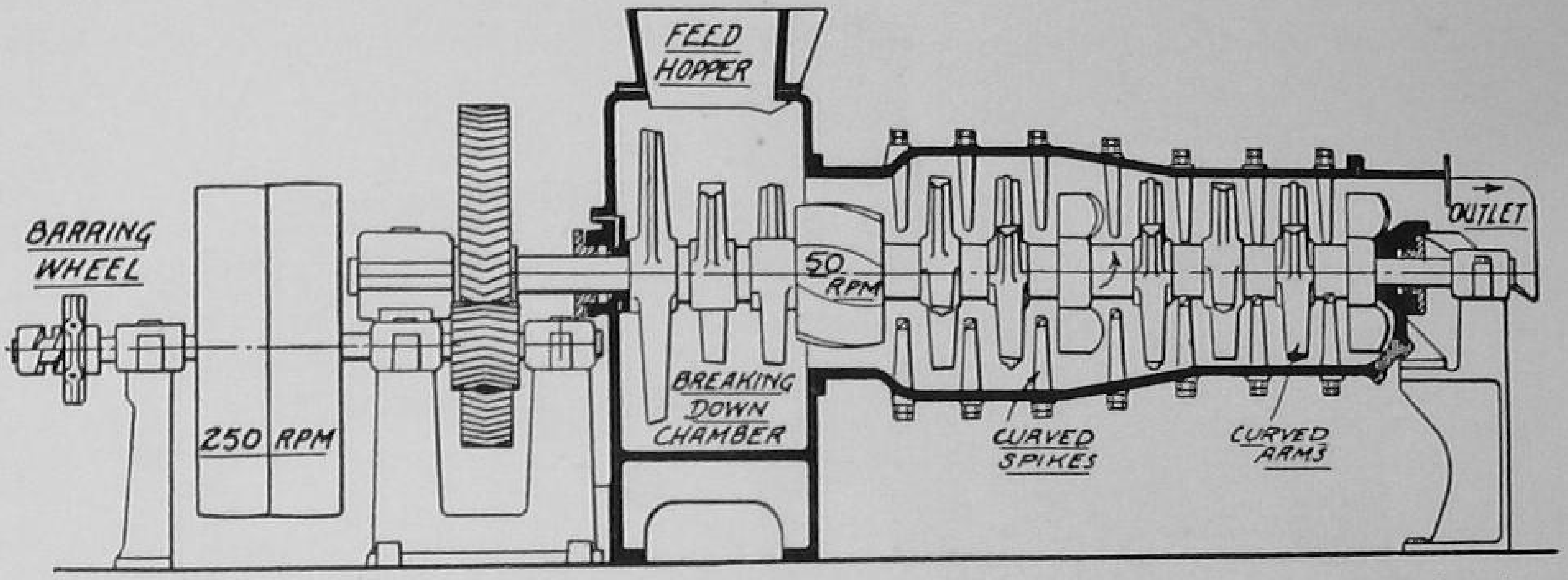
The hydrapulper now provides an extremely useful piece of equipment for dealing with waste paper and broke in the mill. One of the great benefits of this piece of equipment is that it performs, in one operation, what formerly might have had to be done in three different ways. It is not, however, necessary here to explain the working of the hydrapulper, as this is explained in great detail in Chapter VIII.

In order to get the full value of broke from various qualities of paper, a great deal of space is necessary. It is obvious that the broke from an all-rag paper is of much more value than that from an esparto printing, and to take full advantage of that value, the former must be utilized in a similar paper. This necessitates the broke being kept in separate lots until that, or a similar variety, is again being made. This applies especially to coloured broke, which may have to be kept separate for quite a long time.

Very few mills have space for this purpose, and a great deal of good quality broke is sacrificed by being put into cheaper grades of paper.

All broke that is being kept for future use should be packed in good clean bags or press packed into bales and stored in a dry place, well away

from dust and oily machinery. Before going into the boiler or pulper, all broke should be passed over a sorting table with coarse wire mesh top, and well shaken to get rid of dust and foreign material.



[*Watford Engineering Works Ltd.*

FIG. 71.—SECTION THROUGH WATFORD PATENT PULPER, SHOWING DETAILS

Bought waste paper requires to be sorted by skilled sorters in the same way as rags, if it is to be used in good papers, even when bought from waste-paper merchants who grade their paper into special qualities.

The Effect of adding Broke to the Furnish.—A great diversity of opinion is observable among paper-makers as to the effects of adding repulped paper to the furnish. No general statement can, in our opinion, be made. The circumstances of each particular case may differ so much that quite opposite effects may be obtained by apparently the same causes. The only way of giving any sensible explanation is to give instances.

In the case of a machine making waterleaf paper, high-class writings or drawings for hand-sizing, or blottings, with no resin size, alum or loading, it would seem that no doubt would arise as to the effect of adding, say, 10 per cent of the same paper in the waterleaf condition.

It is the fact, however, that the stock may be made either more 'free' or more 'wet'. If the broke is taken straight from the machine to the beater and added to stuff nearly ready to be put down to the stuff chest, the result will be a freer paper. Under these conditions blotting paper will acquire a hard and harsh 'feel'.

This is owing to the fibres having lost their saturated condition coming over the drying cylinders, and to the time in the beater required for pulping being insufficient for them to become again saturated to the same extent. Also, no doubt, some of the finer fibrillæ will have been lost through the wire and suction boxes.

Now, if the broke is filled in with the furnish at the *commencement of the beating*, the fibres will become thoroughly saturated with water and become more highly fibrillated than when first run over the machine, producing a wetter stock. Thus the same quality of broke added at different periods of beating will give two different results. Waterleaf broke that has been stored long enough to have regained its normal hygroscopic condition will invariably, on being repulped, reach the machine in a wetter condition than when it was first made. In this instance the fibres have had time to soften and lose the tension or stress set up by the heat of the drying cylinders, and in a lesser degree by the pressure of the couch and press rolls, and are immediately susceptible to additional fibrillation.

If the broke is packed into the beater in sufficient quantity to increase materially the consistency of the stuff, higher fibrillation is certain.

Broke from tub-sized papers always produces wetter stuff. In most cases it is added in a given quantity with the furnish in the beater, and if it has not been boiled or overheated, the size (gelatine and resin) will still be effective and give hardness and cohesion to the sheet.

Also it shortens the beating time considerably, since its treatment in the pulper or edge runner has produced more fibrillation, and the beater takes up the work at a point a good deal further advanced than when the stock was first made into paper. The other items of the furnish will not require so much beating as they otherwise would, the fibrillæ necessary being supplied from the broke. For this reason all broke from strong papers should be kept for use in the same quality.

Engine or resin-sized broke, usually a lower grade of stock (wood or wood and esparto or straw), has rather a different effect. It produces a paper that feels more pliable and refined than can readily be obtained without it, even after longer beating of fresh fibres. This is especially noticeable with broke that has been through the edge runner, but pulper broke has this effect also, though in a lesser degree. This is no doubt owing to the action of these machines having more of a softening and fibrillating effect on the fibres than the beater.

A very great deal depends on how the broke was beaten in the first place. Broke from fine, free-beaten stuff will usually reduce the strength of any paper into which it is introduced, since the operations of pulping, clearing, etc., must of necessity reduce the length of the fibres still further. This must be borne in mind when using broke in the furnish for thin substances, particularly those with a water-mark, when the too lavish use of poor broke will cause a deal of trouble with pick-ups at the dandy roll. With heavier

substances, water-marking will be assisted, the letters on the dandy roll sinking well into the layer of soft, fine fibres on the surface of the web.

Again, broke, even fine, short-fibred stuff, will increase the strength of paper as in the following instance:

It sometimes happens that a chest of stuff is found to be too raw—that is, insufficiently fibrillated. The resulting paper will have a dull water-mark, a harsh feel and be lacking in strength. An esparto paper beaten thus will give trouble by sticking to the press rolls.

By adding about 10 to 15 per cent of well-cleared broke, the rawness of the stuff will be overcome and the water-mark improved. The strength will be increased because the broke fills up the interstices of the sheet and forms a binding for the long raw fibres. The surface is made more level and uniform and the press rolls do not so readily pluck up individual fibres. As broke usually causes increased shrinkage on the drying cylinders, it may be used to assist in getting the correct register of water-marks. Increased retention of loadings, heavy colours, closer finish, etc., are also gained. Most paper-makers will agree that they would always add broke to the furnish if it were available.

Broke and Waste.—In a mill where there are a great many changes of deckles, etc., owing to the making of small lots, and many different grades and colours, there is, unavoidably, a great deal of broke and more or less waste of fibres. It is essential that this broke and waste be minimized as much as possible, and this depends on the efficiency of the machinery and the skill of the workers in handling it; also on the care taken in the handling of rags, half stuff, reels, sheets, etc. Trucks of rags and half stuff should never be over-loaded or piled up above the level of the edges. An overloaded truck is hard to push about and pieces from its load fall on the floor and are carelessly put back, with sand, dirt or grease adhering, or flung away as waste.

In filling the beaters, no stuff should fall on the floor, but as it is not possible to avoid this on occasion, the floor at the beater side should be kept perfectly clean. There is no reason why this cannot be done, as, with any decent flooring, a flush with water and a sweep off with a broom ought to remove all dust and grit that can adhere to half stuff.

The beaterman should watch his stuff chests carefully so as to avoid overfilling.

The making machine department is where waste is most likely to be caused and broke to be made. Some of the broke is unavoidable; the paring that is left in order to cut off the deckle edge is an instance, and the paper run while changing deckles, dandy rolls, etc. But though a certain amount of broke is unavoidable, a machineman who takes an interest and pride in his

work will try to carry through his changes so that the least possible broke is made. He should make certain in good time that the dandy roll he is going to put on is all correct, so that it will not be necessary to take it off again for cleaning or repairs. As to changes of deckles, etc., it is a good plan for him to work these out on a sheet of paper beforehand, and inform his assistant exactly what he is going to do, and why, so that he can have intelligent assistance at any moment in response to a signal, without loud shouting and confusion.

With regard to the paring or allowance made for cutting off the deckle edges of the web, this must be closely watched. With deckles of about 72 inches, 2 inches are sufficient for rag papers of ordinary quality. This gives 1 inch each side before tub-sizing and ½ to ¾ inch after sizing. Very strong all-rag papers will require 2½ inches, to allow for the greater shrinkage in sizing. Banks, which are apt to have ragged and lumpy edges, and do not, on account of their thin substance, stand well up to the ripping discs of the cutter, may with advantage be allowed 2¼ to 2½ inches. Engine-sized papers of fair substance will be all right with 1 to 1½ inches. Reels that are wound unevenly or slack are a prolific source of broke during later operations, and reach the cutters in such condition that accurate cutting becomes a matter of the greatest difficulty, the cutterman having to keep shifting the brackets in order to keep the web in a central position. It would be an endless task to enumerate all the causes of broke in the machine-room, such as 'pick up', 'felt rubs', etc.; it must be left to the attention and skill of the machineman to keep these in check. A few words might be said, however, about the waste of fibres in starting up and shutting down the machine.

In shutting down a machine to 'wash out' for a fresh lot, the machineman will be guided by circumstances. If colour and furnish permit, the stuff service system need not be emptied, and here the sequence of colours, furnishes, etc., is important.

Waste occurs every time a chest has to be washed out, and by arranging lots in proper sequence, starting from a low shade and working up to yellows and blues, for instance, this waste will be cut down to the minimum. The stuff gate being shut, more water should be put on and the level of the shutes and strainers maintained until the stuff loses so much consistency that the wire can no longer form it into a web. The machine may be slowed and the stuff run up the press roll when the proper substance is lost. This will save a great deal of fibre that might otherwise be run down the drain.

When it is necessary to empty the chests and service system, the simplest plan is to run a good supply of water into the chest when the pump shows signs of losing grip. The pump will take the water from the chest and flush

the remainder of the fibre from the pipe and stuff box. The pulp recovered by these means may not be so clean as the ordinary broke, owing to the flush of water disturbing the sand traps, but it may be used with care in lower qualities of paper. When it is realized that in the bottom of the chest, in the stuff pipe, stuff pump, stuff box, shutes, strainers and connecting pipes, there may be from 50 to 200 lb. of fibres, the importance of a little care in this connexion is manifest. A careless shut-down may easily cost the mill £50. Again, when starting up it is a very wasteful and reprehensible practice to run the first flush of water and stuff down the drain in order to get full weight on putting the wire in gear.

The machine should be slowed down, so that a start can be made with the first flush of stuff. It is quite a simple matter to speed up after a few minutes.

When starting up the machine it will be found that the paper does not come up to the proper shade for some time. This is due to the use of fresh water at the start, and when the backwater begins to circulate, the colour loading, etc., will gradually work round. In very deep shades the colour will be nearly ¾ hour before it is quite settled. Ordinary white paper coloured with a little ultramarine blue will come up in 15 to 30 minutes.

Also, no doubt, however well the machine has been washed up, the paper will contain specks of dirt, strings of fibres from the strainers and bits of coloured pulp from the previous lot. In some mills it is customary to run the web up the press rolls for a time on starting. Others get the web right away to the reel as soon as possible. In the first case the wet broke is easiest to re-pulp, but has the disadvantage that the handling of it is more difficult and often leads to its getting dirty. In the second case the machinemen, once the paper is on the reel, can get the substance, dandy register and drying right, and by the time the colour has been approved the paper is correct. A fresh reel can then be started and the first piece torn up.

Most paper-makers are unwilling to tear up as broke any paper that has been run on the reel, and are tempted to let the doubtful start go through in the hope that some of it will be good. But if the paper is intended for tub-sizing it must be remembered that the size used for the bad sheets is waste, and so is the labour of cutting and sorting.

In the following operations of tub-sizing, drying, etc., close attention on the part of the workers is necessary at all times to prevent blemishes and breaks. Slips or sheets, torn from the reel at the machine, are frequent causes of broke, and the fewest possible should be taken by the machinemen, and these should be flagged.

Broke must not be allowed to lie about on the floors to be trodden on

and thus rendered useless for repulping; cleanliness of the floors, machinery and the *hands of those who touch the paper* is imperative.

All dry broke should be immediately put into a baling press to keep it clean, and to enable proper bales to be made, so that if the broke cannot be immediately re-used, it can be properly stacked and stored in the broke store in a clean and orderly manner. Baling all broke has the great additional advantage that it can be easily marked and *weighed*, so that proper records can be kept of the waste and spoilage, which is such an important part of mill costing, and which is very difficult if broke is kept in a loose state.

Treatment of Wet-Strength Broke.—The very nature of wet-strength paper makes it difficult to re-pulp by orthodox methods, and unless suitable precautions are taken stuff pumps can easily become choked. Provided the broke is not allowed to dry, no difficulties are encountered, but dry broke and wet-strength paper from outside sources require special treatment. Although heat and an excess of alum are needed to cure the resin in the dried paper, the same two factors effect hydrolysis of the resin and break-down of the resin-cellulose bonds under wet conditions. Wet-strength broke should therefore be subjected to mechanical disintegration in hot water (70°–90° C.) at about pH 4·5 in order to defibre it completely.

CHAPTER XII

ROSIN SIZING—STARCH—SILICATE OF SODA—ALUM—LOADINGS

Resin, rosin or colophony is the solid residue of the gums or juices of coniferous trees after the evaporation of their moisture and volatile substances. It is a weak acid, to which the name abietic acid is given. Its colour ranges from a light pale yellow to a dark brown, according to its source and the temperature used to drive off the volatile substance. It is insoluble in water, and, when broken, the fracture shows a clear, glassy surface.

When exposed to light and air, resin changes into a crystalline substance, becomes friable and loses its amorphous quality. This explains why resin-sized papers gradually deteriorate, losing colour, strength and ink resistance.

Resinate of soda, resin soap or resin size is made by boiling resin with soda ash or with caustic soda. Resin size is soluble in water, but there is always a certain amount of free resin present, unless the soda has been used in such proportion as to balance exactly the acid resin, when the size is called neutral. Size which has much free resin (20 to 25 per cent) is of a creamy or white colour, and is called 'white size', to distinguish it from the other, which is brown in colour.

Resin size is generally made by boiling powdered resin with a solution of soda ash in an open steam-heated vessel, the proportions being about 1 lb. of soda ash to $6\frac{1}{2}$ or $7\frac{1}{2}$ lb. of resin. This would produce a size with about 10 to 15 per cent of free resin with 7 hours' boiling. Those paper-mills which make their own size have found by experiment the proportions that are most suitable for their stock and for the hardness of their water.

Although it is about 130 years since resin was first found to have sizing qualities, it still remains a matter of controversy as to the exact action which causes it to be a sizing agent. It was held for a long time that resinate of alumina (the precipitate of resin size and sulphate of alumina) was absorbed by, or stuck to, the fibres, and filled up air space in the paper in much the same way as gelatine size does.

Modern chemistry offers another and more probable explanation. In the mixing of the relatively small quantity of size in the beater of stuff and water, the size is so much diluted as to be resolved into its component parts, free resin and sodium hydroxide. In the same way, hydrolysis of the sulphate of alumina produces, in its place, sulphuric acid and aluminium hydroxide.

The sulphuric acid and sodium combine to some extent to form neutral salts, thus leaving as effective agents for sizing the *free resin particles* and *particles of aluminium hydroxide*.

Now, research into electro-kinetics has shown that some substances are charged with positive and some with negative electricity. Substances of opposite charges attract each other. It will at once be seen that this has a vital bearing on the subject.

Fibres suspended in water are charged negatively, so also are the minute particles of resin. Therefore the addition of resin particles to the beater will not result in the fibres being covered by the resin. They will be repelled instead, and anyone who has watched the behaviour of stuff and resin size in a beater before the alumina has been added will at once perceive that some disturbing action is taking place which seems to be too great to be accounted for by the formation of gas, causing an increase in bulk.

The particles of aluminium hydroxide, on the other hand, are charged with a positive charge. On the addition of the alum solution the disturbance in the beater subsides and the stuff contracts in bulk. The cellulose has attracted to itself the positively charged aluminium, and as this is always added in excess, it may be concluded that the negatively charged fibres have now become positively charged, or at least coated with the positively charged aluminium particles. Thus the fibres are now in a condition to attract the negatively charged particles of resin, when we may assume that the action has ceased.

The excess of alumina assures that no resinous particles will remain unattracted by the fibres or by the alumina particles.

On passing over the machine, some of these wandering particles of resin and alumina will pass through the wire with the water, but the bulk remains on or between the fibres, forming an ink-resisting coating or filler for air spaces.

It has generally been assumed that the resin size must be first added to the stock in the beater, so that it may be 'beaten into the fibres', but this theory seems to indicate that the opposite would be more effective. Indeed, many mills *do* hold this to be the case, and put the sulphate of alumina solution into the beater first, to neutralize the hardness of their water, and find their sizing improved thereby.

The history of sizing is most probably as old as that of paper-making, as there is very old evidence that it has been usual to treat paper with natural gum or mucilage to make it stronger and more resistant to water and ink.

Modern sizing can be described as a sort of intimate coating of paper-

making fibres with a material which is insoluble in and repellent towards water.

The material used originally and still most widely used to-day is resin, and since M. Illig's days, when so-called 'engine' sizing was first introduced around the start of the nineteenth century, there has been no appreciable and fundamental alteration in the manufacture and use of 'Resin Size' until the advent of 'Bewoid Size'.

Since the early days of 'engine' sizing with resin solutions or emulsions, it has been widely held that uncombined resin, suspended in small particles in the alkaline resin solution, was a more efficient sizing agent than the fully saponified resinate of soda, while a high uncombined resin content in the size was also an insurance against froth trouble. The absence of active alkalis also increases the life of wires and felts and less alum is needed to bring the pH of the paper stock to the necessary acid condition.

The amount of alkali needed to make a fully saponified solution of resin in water is approximately 11 per cent NaOH on the weight of the resin, in which case there is no uncombined resin. Most paper-makers and size-makers have developed means whereby the amount of alkali is reduced, allowing a portion of the resin to remain uncombined—the use of soda ash (Na_2CO_3) in place of NaOH is also practised in many mills.

In open pan boiling, a reduction in the amount of alkali, coupled with a long, slow cook, makes a size containing an appreciable amount of free resin. On the other hand, so-called pressure boiling, with a minimum of alkali and subsequent injection into cold water, as in the 'Erfurt' system, was also successful.

All these methods, however, had certain drawbacks. They needed careful supervision to ensure that the cooking was thoroughly carried out, or the uncombined resin remained in large enough particles to cause specks in the finished paper. In the best of these so-called 'Free resin' sizes the highest theoretical amount of free resin possible was 40 per cent of the total resin content, and this was very seldom achieved in practice.

It is claimed that the first real 'Free resin' size was Bewoid, which is made by a new process. The resin is first melted, then cooled by the addition of a casein solution and water, while agitating the resin at comparatively high speed. It should be noted that only the resin is heated, not the water, so that the use of steam to raise a quantity of water, upwards of three times the amount of resin, to boiling point, and to hold it at that temperature for some hours, is avoided.

The high concentration of Bewoid and Bewoid Papercoll sizes, from 45 per cent to 60 per cent solid content, makes storage easy in a small place;

economical to transport and in use, Bewoid size, whatever its concentration, can be used straight from the drum into the beaters.

Since its inception Bewoid (all-resin) size has remained almost unaltered, apart from minor changes in formula and technique, designed to improve stability, increase resistance to extremes of temperature, and simplify the making.

Bewoid Papercoll sizes, such as 'Alpha' and 'Beta', were developed over a period of time, to improve the sizing efficiency and the resistance to temperature extremes; further, to increase the concentration, for purposes of economy in transport, to reduce the amount of high-priced materials in short supply and to include certain raw materials not hitherto thought suitable for paper sizing—all of which appreciably reduces the cost of sizing to users.

Incidentally, it was found that by increasing the concentration, the relative efficiency of the size was also increased. An increase of 50 per cent in concentration in one case gave an increase of 100 per cent in sizing value, or an increase of 25 per cent in relative efficiency.

Furthermore, due to the great reduction in the amount of sulphuric acid liberated in the beaters, the life of felts and wires has in some instances been increased quite enormously. Makers of fine-class papers and boards have obtained a very pronounced brightening in the shade of their papers, especially in this regard some outstanding results have been obtained by many well-known mills in Britain and in other countries.

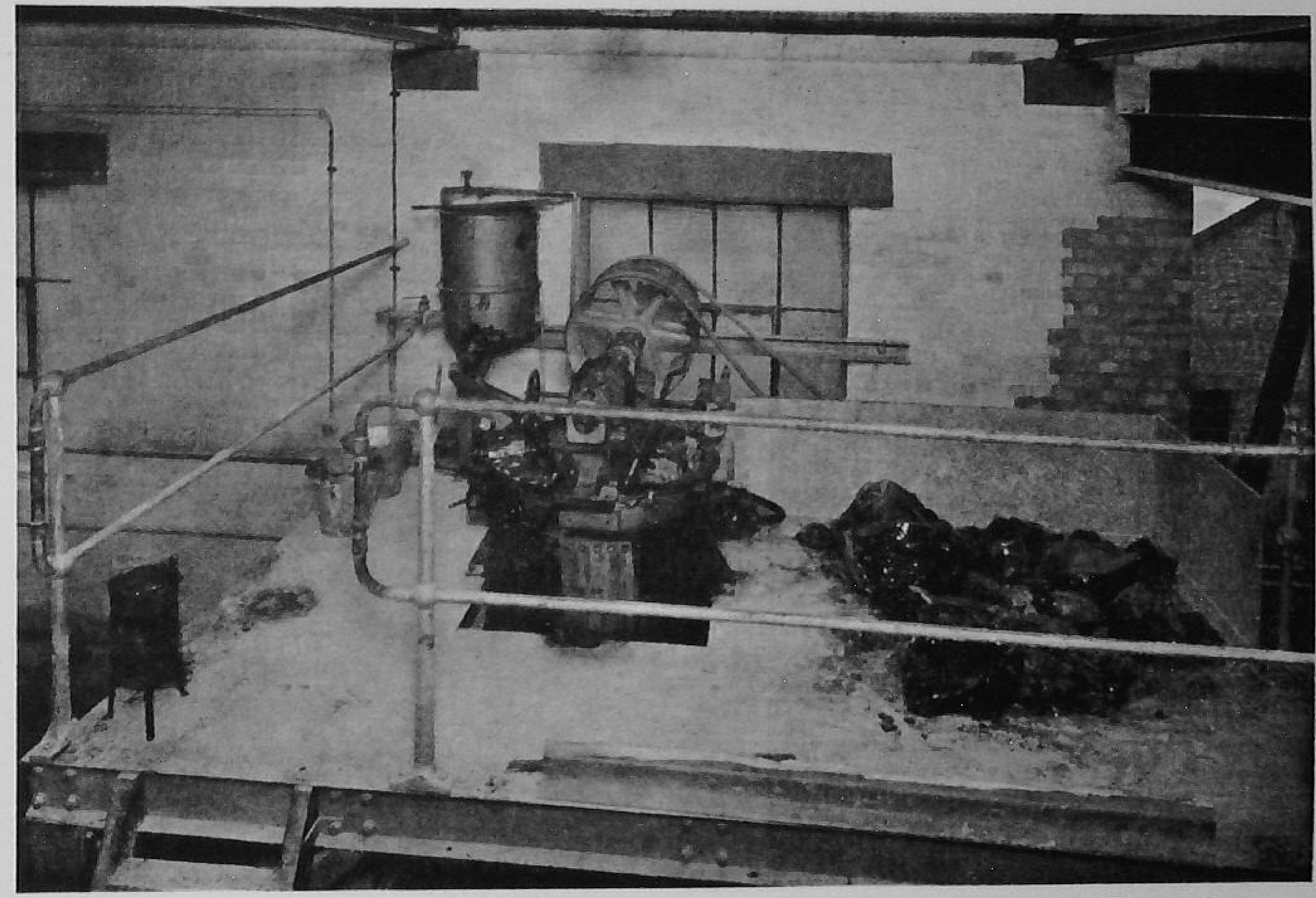
In appearance 'Bewoid' and 'Bewoid Alpha Papercoll' sizes are milk-white fluids, while 'Bewoid Beta Papercoll' size is a light brown fluid. All these grades can be used undiluted straight from the drums into the beaters, which saves a great deal of labour, space and extra expense.

The resin is present as particles of free resin, averaging $\frac{1}{1,000}$ millimetre in diameter. The particles can be observed and measured with a high-power microscope, and the 'Brownian Movement' of the particles is clearly visible, which is a sure indication of the high stability of the dispersions.

While 'Bewoid Papercoll' sizes have a high degree of stability under most conditions, they are liable to separate under the influence of severe frost. Being neutral mechanical dispersions, they remain separated after thawing. It is therefore necessary to incorporate a frost-resisting agent with the size during the seasons when it is liable to encounter severe weather. It is still advisable to store the size under cover during the winter.

The Bewoid mill consists of the following parts: A steam-jacketed cylindrical pan of 125 gallons capacity, with a manometer, safety valve,

blow-off cock and steam trap. The vertical spindle extends through the bottom of the pan to a ball-bearing, and continues through the top, with



[*Becker & Co. Ltd.*

FIG. 72.—BEWOID MILL, SHOWING STEAM-JACKETED PAN, MEASURING VESSEL AND SUPPLY OF RESIN

bevel wheels, to a horizontal shaft fitted with two specially designed impellers. This is arranged to run at 70 to 200 revolutions per minute by means of a two-speed motor. There is also a measuring vessel of 130 litres capacity graduated in 20-litre divisions, with a 2-inch and $\frac{1}{2}$-inch run-off pipe to run into the Bewoid mill. The measuring vessel is supplied with a steam- and water-pipe. There is also a small copper measuring vessel of 7 litres capacity on a tripod stand. The method of preparation is as follows: The resin, 560 lb., is melted without water in the Bewoid mill. Melting is assisted by circulating at the slow speed. When European resins are used, the resin should be brought up to a temperature of 140° C. during melting, so that any crystals of a high melting-point will be melted. When the resin is melted the steam is turned off, and agitation started at the high speed; 9 lb. of caustic soda in solution is run in slowly through the 7-litre vessel. While this is running in, the casein solution is prepared; 20 litres of

water is run into the 130-litre vessel. The steam which is taken to a jet at the bottom of the vessel is turned on and 12 lb. of casein tipped in. With the steam still on, 1 lb. 2 oz. of caustic soda in concentrated solution is added, and the solution stirred quickly. The temperature should not be higher than 82° C. This is diluted to 60 litres at 33° to 43° C., depending on the melting-point of the resin. When mixed, a further 1 lb. 2 oz. of caustic soda is added.

When the 9 lb. caustic solution is all added to the resin, it is necessary to cool the resin further to 100° C. This can be done with water, or more conveniently by using part of the casein solution through the ½-inch pipe. The correct temperature is easily observed by the sudden drop in the amount of steam given off. If casein solution is used for this cooling, the amount used must be replaced with water, and the bulk and temperature of the casein solution brought up to the original figures. This 60 litres of casein solution is run into the resin through the 2-inch pipe.

Recent research made by well-known paper-makers on the Continent has brought forward new and interesting facts as to what compounds are actually responsible for the sizing of the sheet.

It was observed that satisfactory sizing is not necessarily dependent on the degree of acidity at which the sheet is made, but that the most important factor in obtaining a satisfactory degree of sizing appears to be the volume of concentrated aluminium ions or compounds. For example, due to factors not always properly controlled or adjusted, paper may be made at a pH of 4½, whilst there are in fact no or very few aluminium ions present in the stuff.

The reason is that these ions are primarily absorbed by the fibrous stuff whilst at the same time, if a highly or partly saponified resin size is used, the latter also absorbs quite an appreciable quantity of aluminium ions.

At the start of the sizing operation both the fibrous stuff and the size are ionized equally. It has been found that at a pH of 6·8 using Bewoid size an ionization of the resin particles takes place, however, without the effect of a full precipitation, which is in contrast to other types of resin size, prepared by a number of different methods, thus obtaining a full quantitative precipitation only some time afterwards, which can be estimated to be in the region of 1½ hours. The resin precipitation is thus held very firmly to the fibre, because all ions (aluminium compounds) can be absorbed by the fibre. There has therefore taken place a partial or preliminary acidification of the fibre, whereby, on account of the very low saponification figure with Bewoid size, very few aluminium ions are absorbed by the latter at this initial phase.

From this it would appear worth while to add a small quantity of aluminium sulphate to the beater before commencing the actual sizing operation.

In many, if not in the majority of cases, where saponified papers are attributed to the quality of the size employed, this would not apply to an almost 100 per cent free resin size like Bewoid size, as it needs, generally speaking, no increase in the concentration of aluminium compounds.

A resin-wax size can also be produced by the Bewoid process. This may be used for special papers, but has the effect of reducing strength and making a limp and flabby paper.

After 5 minutes the dispersion is diluted with water at 38° C.: first, 70 litres through the ½-inch pipe, and the remainder through the 2-inch pipe. As the colloid rises up the sides of the pan during dilution the slow speed is started, and the mill is finally filled and the agitation stopped. When filled, the size is of 45 per cent concentration.

Skin glue can be used as a colloidalisator in place of casein. This gives improved sizing, but the colloid is less stable.

When using glue, only 8½ lb. are used at 50° C. in 60 litres, without caustic soda. The glue should be soaked for ½ hour before using. Only 8 lb. 6 oz. of caustic soda is used instead of 9 lb., as when using casein, for the first cooling and neutralizing of the resin.

Starch.—In very ancient times starch was the only material known for the sizing of paper. It is now used in addition to other sizing agents to give a hard rattle and an improved finish to paper. A slight increase in strength may also be obtained by its use. It increases transparency, especially in highly glazed papers.

A great deal must be used to get much result, as it readily drains out on the wire and suction boxes. As it is carried mechanically by the fibres, the size of starch granules is important. Those of potato starch are largest, maize smaller and rice smallest of all.

Each granule is a little capsule or container filled with a gelatinous substance. The heat of the drying cylinders, acting on the wet granule, causes it to swell and burst, the contents fusing and binding the fibres together. Starch is better retained by the stock in the presence of sodium silicate in the proportion of 1 pint of sodium silicate to 5 lb. of starch. These may be mixed together with warm water, then heated until the starch is partly 'burst' and cooled with a little cold water to stop the action. This is called starch silicate; the precipitate is very white and has more hardening effect on the fibres than starch or sodium silicate used alone. About 2 pints of silicate and 10 lb. of

starch are required for 4 cwt. dry weight of stock. Less resin size is used in this case.

The usual amount of alum has to be slightly increased to precipitate the starch silicate thoroughly. Starch is, however, an expensive material to use, and in free beaten stock its effect may be entirely lost. In well-fibrillated stuff, which carries the granules in greater quantity, its results are more apparent.

Silicate of Soda.—The use of silicate of soda ('waterglass') as an auxiliary sizing agent is gradually becoming more general, and excellent results may be obtained by using the silicate either alone or, more often, in conjunction with resin size and starch.

The silicate is a compound formed by the fusion of silica with carbonate of soda, and at ordinary temperature it is a thick, syrupy, sticky liquid which hardens on exposure to air. It is readily soluble in warm water, and it is often necessary, especially in cold weather, to add warm water to it before furnishing to the beater. If this precaution is not taken, the silicate sinks to the bottom of the trough and lies there, forming a hard, glass-like coating.

Silicate of soda is an alkaline substance, and is precipitated by alum, in much the same way as resin size. It does not actually resist aqueous inks by itself, and for this purpose requires the addition of resin size, the retention of which, along with starch, colour and fillers, it greatly assists, so that it may ultimately help in the production of a more ink-resisting paper.

Silicate increases the strength of most papers, drying hard and white, and it also gives a greatly increased rattle and firm 'handle' to all papers. It may be used with advantage to assist in making the stuff work 'wet' on the machine, as it helps in the retention of water in poorly fibrillated or 'free' stuff.

As it is very resistant to oils, the silicate may be used to great advantage in the making of printing papers and posters which have to resist an enormous amount of coloured and oily inks. It also has the effect of assisting the paper to resist the deteriorating action of sunlight.

While resin-sized papers are often inclined to be sticky at the press rolls, silicate of soda helps to eliminate this trouble, and it also reduces cockling and drying defects and helps the paper to lie flat when cut.

The cementing action of the silicate on the fibres keeps down fluff, and this is very beneficial in papers which have to be clearly punched or perforated with small holes or cut into narrow strips.

Silicate of soda may be used to replace part of the resin size, and thus reduce considerably the cost of sizing, or it may be used as an auxiliary sizing agent, along with the usual amount of resin size. In this way it will impart

additional qualities to the paper, such as hardness, 'snap' and increased strength.

When the silicate, along with the requisite amount of alum, is added to the beater, a light and bulky precipitate is formed in contact with the fibres, and as the precipitate sticks to the fibres themselves, most of it is carried across the wet end of the machine and is not lost in the backwater.

It is also claimed that the precipitate of silicate, which consists of aluminium oxide, aluminium silicate and silica, retains 25 per cent of its weight of moisture when passing over the machine under the normal conditions of drying, and this would assist in the subsequent calendering where a high finish is desired.

It is most important that sufficient alum should be used in the precipitation of the silicate, as the silica itself gives a slightly alkaline reaction with litmus. The contents of the beater must therefore show a definitely acid reaction, otherwise a great amount of the value of the silicate will be wasted.

The proper order for the furnishing of the beater is to add first the silicate of soda and, after it has become thoroughly mixed with the stuff, sufficient alum to precipitate it completely. If resin size is also being used it should be added later, and, finally, the alum for the resin.

As silicate of soda is manufactured in many different forms of solution, differing in viscosity, density and alkalinity, great care must be used in selecting the most suitable kind for sizing paper.

The amount of silicate to be used depends upon the kind of paper being made, the substance of the paper and the effect that it is desired to produce. If it is desired to make a paper with a very hard rattle, as much as 3 or 4 per cent of silicate may be used, but to improve the hardness of a well-sized writing paper, $\frac{1}{2}$ to 1 per cent will be sufficient.

Silicate may be used with great advantage in conjunction with starch. The starch-silicate is made by mixing the two substances in a predetermined proportion and heating with water to about 65° C. until the starch has burst. The mixture is then added to the furnish and sufficient alum added to precipitate the silicate.

Starch being much more expensive than silicate of soda, the proportion of silicate to starch should be carefully regulated in order to ensure the best sizing and hardening results at the lowest cost.

Paperine.—Paperine is a preparation of farina which is treated with caustic soda and acid to produce a cold-water-soluble starch substitute. This material is much more economical in use than starch, being retained in the paper to a remarkable degree. Normally $\frac{1}{2}$ to 1 per cent on the dry weight of the beater is sufficient to give increased strength and handle. It is best to

add it dry to the beater, when furnishing in very small amounts, through a small open sieve, which prevents the formation of coagulated lumps. These are very difficult to dissolve and cause sticking at the press rolls, but with normal care there should be no trouble from this source.

Alum.—This important chemical compound finds many uses in the mill, and it can be truly said that it is an indispensable ingredient for most papers.

Aluminium sulphate, $Al_2(SO_4)_3$, is made in three grades. The best grade, which is used in good quality writing papers and other papers which have to be free from iron, contains 17 to 18 per cent aluminium oxide (Al_2O_3) and is practically free from iron. The second quality contains 14 per cent of aluminium oxide and a small percentage of iron, usually about 0·12 per cent or less. The third quality, usually called alumino-ferric, contains considerably more iron than the other two, and is only used in low grades of paper; it is also used for the purification of water.

For the highest grades of writing paper, potash alum, $Al_2K_2(SO_4)_4,24H_2O$, or crystal alum is still used. This is an almost colourless salt of aluminium and potassium sulphates, but it is very much less soluble in water than the aluminium sulphate and much more expensive.

Alum or aluminium sulphate is generally made into a solution with water before being added to the beater, although it is the practice in some 'news' mills to buy it 'kibbled' or in powder and put it dry into the breakers.

The best way to prepare the solution is in wooden or lead-lined tanks or chests having lead pipes and taps. Iron or brass must not be used, as the free acid will eat these away. Wooden tanks are usually provided, two for dissolving the alum and a third and larger tank as a store, from which the solution is run by gravity to the beater room or carried in wooden buckets.

A satisfactory method is to have a wicker cage or basket which will conveniently hold the contents of one or more bags of alum, and suspend it by means of a wooden pole across the top of the tank at such a height that the water in the tank can reach well up the cage. The alum is put into the basket and the tank filled with water. As soon as the water reaches the alum it readily dissolves, and the saturated solution sinks down in the chest, allowing fresh water to reach the alum. The action may be accelerated by rocking the basket on the pole or by causing the circular cage to revolve.

The saturated solution will stand at about 62° to 64° Tw., and a gallon of the solution will contain about 3½ lb. of aluminium sulphate. For convenience in working in the mill, the solution may be diluted to 20° Tw., in which case a gallon will contain about 1 lb. of alum.

The chief uses to which alum is put in the mill are:

1. For the precipitation of resin size.
2. For the precipitation of starch.
3. For the precipitation of silicate of soda.
4. To brighten the colour of the paper.
5. To help the resistance of the paper to ink.
6. To soften the water if it is hard.
7. To prevent or lessen frothing at the machine.
8. For the preparation of gelatine size for tub-sizing and to prevent putrefaction.
9. To assist in the bleaching of rags.
10. As a mordant for certain dyestuffs.

The acidity of sizing agents is now controlled by pH value, as are many other reactions in the paper-mill.

A solution of alum is always dirty and full of jute, hairs, etc., from the bags in which it comes, so that it must be carefully strained through flannel over a fine-mesh wire cloth when it is being put into the beater, or it may be strained when being run from the dissolving tanks to the store tank.

The furnishing of dry alum direct into the beaters is not to be recommended, even in news mills, as the hairs and other impurities contained in it foul the sheet, and also are frequently the cause of breaks at the machine. The provision of proper dissolving tanks is a simple and inexpensive way of avoiding this trouble, and it is also more economical in the long run.

Loading.—There are two reasons for the loading of paper with mineral substances. The first, and no doubt original reason, is for the purpose of producing a cheaper paper by substituting loading for fibre. As there is no record of the introduction of this process, we may conjecture that some astute paper-makers kept the secret to themselves and reaped a rich harvest until it leaked out.

The second is that the use of loading, or fillers, imparts special properties to papers, and it is therefore a necessity for some classes of paper.

The most important of these fillers is china clay or kaolin. This is the remains of very ancient deposits of felspar or granite. Its chemical composition is about half silica (SiO_2). The other half is made up of about 35 to 40 per cent of alumina (Al_2O_3), 12 to 15 per cent of water and traces of various substances such as calcium, magnesium, iron, mica, etc.

It is found in Cornwall and Devon, but huge deposits exist in many other parts of the world. It is usually found close under the surface, and is dug out so that great pits are made. It is not usable without treatment, as it is mixed

up with sand and grit, mica particles, etc., and must be refined and cleaned to be of any use to the paper-maker.

The clay is broken from the face of the pit banks by directing against it a jet of water at high pressure, or by men with picks, who break down the clay and direct it into a flowing stream of water. It is allowed to settle at the bottom of the pit long enough to let the heavier substances fall to the bottom and the clay suspended in the water is pumped to the surface. It then passes through 'mica drags' or shutes; the finer particles pass through screens, leaving mica behind. The stream of water and clay is then run to settling ponds or pits. From thence it is run to storage tanks and the clay falls slowly to the bottom, leaving the clear water at the top. The water being run off, the clay is dried in drying pans or kilns and broken up for use.

As may be expected, there are many grades of clay. The best qualities are free from grit and sand, and the particles are very fine and white. These are used for coating papers. Most paper-makers' clays contain more or less mica, according to the quality, and this shows up in paper as glistening specks. Clay is of a colloidal or plastic nature when mixed with water. The old circulating tanks used in some mills, combined with strainers, to separate the clay from grit, etc., have in many mills given place to centrifugal machines, which are more positive and continuous in their action.

Another important filler is calcium sulphate ($CaSO_4$), known also as gypsum, terra alba in its natural state, and as pearl hardening, crown filler, satinite, etc., in the artificial production. Gypsum and terra alba are the ordinary mineral, ground fine, and have a crystalline structure. Pearl hardening is prepared by precipitation with acid and is of a fine white colour, clean and free from grit. It is partly soluble (1 lb. to 45 gallons of water), and therefore a great deal is lost if the backwater of the machine is not well conserved. It can be used to improve the colour of high-class papers. As satin white, in paste form, it is used for paper coating.

Magnesium silicates in the form of asbestine, agalite and talc are sometimes used as fillers, the particles being of a fibrous form, and well retained by the paper; they are also 'soapy' and give a high finish. Barytes and blanc fixe are forms of barium sulphate. The latter is the precipitated quality and is sold in paste form for paper coating.

Almost every paper of any substance, except hand-made and some very expensive all-rag papers, contain mineral loading. All printing papers require china clay, which enables the paper to have a close regular finish, and is very absorbent of printer's ink, besides allowing a cheaper paper to be produced. It also takes colours well and brings up the brightness of the shades. Used in moderate quantity in blottings, it gives a soft, smooth feel,

taking away a good deal of the harshness of the fibres, and helps in the retention of the dyes, which in this case have to be used without a mordant.

Calcium sulphate fillers are not used to such an extent as china clay, but produce much the same results, except that they do not give the same limp feeling and are less inclined to make the paper soft and flabby.

All these loadings, however, reduce the bulk of the paper, being twice the weight of fibre, bulk for bulk.

Opacity being necessary for papers such as envelope papers and printing papers, these are usually well loaded, china clay being the filler most in use. Writing papers may have up to 15 per cent of loading, usually china clay and terra alba in equal proportions; S/C printings up to 25 per cent of china clay, and in the case of imitation art, as much as it will carry, which, of course, depends on the substance and may be as high as 30 per cent. A good heavy filling of china clay reduces the expansion and contraction of litho papers.

The retention of loading varies considerably. China clay may be retained to the extent of 80 per cent of the quantity put in the beaters, but is usually about 50 per cent unless a closed backwater system is used. The retention is governed by many factors, the chief being the degree of fibrillation of the stock, the thickness of the paper, the nature of the loading, the characteristics of the fibres used, the formation of the sheet on the machine, the size or other binding substances put in the beater, the conservation of the backwater and the length and flow of the machine shutes.

Well-fibrillated stock, and fibres that are very fine and pack closely in paper, such as esparto and straw, have a high retention. Free stock for blottings and harsh fibres like soda pulp from coniferous wood have a low retention.

Papers that are heavily resin-sized or have starch, silicate of soda or other binding substances will carry a heavy percentage of loading.

The formation of the sheet on the machine will, of course, depend on the beating of the stuff, but too much water on the wire will mean a loss of loading by excessive suction on the boxes. Up till recently, it has always been an established practice to add the loading—whether it was clay, chalk or other mineral—to the beater, it being always maintained that if the loading were well beaten into the stuff a greater proportion was carried through into the paper, and less came away in the white water; this theory has been found erroneous. Much better results are now being obtained by adding the loading with water in a thin continuous stream to the stock before it goes on to the machine, before the strainer, but after the centrifuge. In this way there has been found to be a saving in the amount of loading required to give a predetermined quantity in the paper. Opacity has been improved, and less

loading has had to be dealt with in the backwater. There is the additional advantage that the beaters hold more stuff and the beater bars and plates last longer, owing to the absence of the abrasive action of the clay. The bottoms of the chests and chutes are not filled with loading, and lastly the centrifugal machines are not rapidly filled with large quantities of loading in the bolsters. This method of adding loading gives much greater control over the quantity, and the amount being carried in the paper can be altered in a minute or so instead of having to wait for another engine, or a chest of stuff to be worked out.

The use of calcium carbonate as a loading has, in the past, been restricted to certain lightweight speciality papers like Bible paper and cigarette paper. Recently, especially in America, it has found use in other grades mainly on account of its power to impart whiteness, opacity and good printing qualities. The better grades of calcium carbonate used in the speciality papers are specially prepared chemically precipitated products of very high purity, and considerable skill is used by the manufacturers in the control of particle size and crystal form. This chemically precipitated product can be produced in both of the natural crystal forms as either calcite or aragonite. Coarser grades of calcium carbonate are available from ground natural chalk deposits or from by-product chalk.

Wide use of calcium carbonate is prohibited by its reactivity with the slightly acid alum used in normal resin-alum sizing, although calcium carbonate loaded paper can, of course, be sized with neutral wax emulsions.

Magnesium carbonate is used together with, or as a replacement for, calcium carbonate in similar speciality papers, especially cigarette paper. It is notable for its whiteness and opacity-giving qualities.

Titanium dioxide is outstanding as a loading on account of its high refractive index, small particle size and chemical inertness. By its high refractive index it imparts opacity to the paper sheet and is usually only used to the extent of a few per cent. Titanium dioxide is available either as the 'pure' product or co-precipitated with calcium sulphate or barium sulphate as a pigment containing 30, 50 or 70 per cent titanium dioxide. The opacity-giving power of the mixed pigment is not as great as the pure product, and there is little evidence that, owing to the greater usage of the mixed pigment for a given gain in opacity, there is any economic gain by its use. Titanium dioxide is unaffected by sizing materials or any other furnish constituents. In all forms, titanium dioxide is relatively expensive and, during its use, backwater systems must operate at their highest efficiency to avoid undue loss of the loading.

CHAPTER XIII

DYEING OF PAPER

The colouring of paper to shade is a difficult process but a full understanding of the many variables and of the products used to obtain coloration will do much to minimize the difficulty.

Some knowledge of the various types of dyestuff products is essential, and in this connexion the following classification with description of the general properties of each group will be of value.

Dyestuffs for colouring paper may be divided into:

1. Natural dyestuffs.
2. Synthetic pigment dyestuffs.
3. Synthetic soluble dyestuffs.

Natural Dyestuffs

The natural organic dyestuffs—for example, logwood, madder, cochineal, etc.—are little used in the dyeing of paper and may be discounted since they are difficult to apply, require the use of mordants or other chemical treatments and give results which are obtainable more easily by the use of synthetic products.

Natural inorganic products are much more used however, and may be dealt with in a little more detail. All these are pigments; that is, they are not soluble in water.

Sap Brown or Van Dyck Brown is a dark brown pigment occurring naturally in peat and brown coal deposits mined originally at Meissner near Cassel and in the vicinity of Cologne, and is used extensively for the production of cheap fast-to-light browns. The shades are, however, not fast to alkali, acid or chlorine.

Iron Oxides occur naturally as a pure form of red haematite or native ferric oxide Fe_2O_3, but the bulk of the oxides used nowadays in paper dyeing are obtained synthetically. The shades obtained from iron oxides are very fast to light, acid, alkali and chlorine.

Ochres occur in pockets in stratified rock and many may be regarded as clays, being high in aluminium silicate content, although the main mineral content is $Fe_2O_3 3H_2O$.

Roasting or calcining produces burnt ochre, the shade becoming

progressively redder as more water is lost until the final colour of ferric oxide (red oxide) is obtained.

These ochre pigments are being replaced, however, by ochre substitutes which are soluble synthetic dyestuffs.

Synthetic Pigments

Prussian Blue is a pigment widely used in the paper industry both as a paste and in the powder form of soluble Prussian Blue, which is a specially prepared precipitate of small particle size which in water forms a clear colloidal solution. It is ferric ferrocyanide and is produced by the precipitation of a ferric salt with sodium or potassium ferrocyanide.

Prussian Blues give shades fast to light, acid and chlorine, but fugitive to even dilute alkali.

Lead Chromates are mixtures of lead acetate and sodium bichromate producing yellow to orange shades according to the proportions of each used. The products may either be produced in the beater or used as obtained from manufacturers in the form of a pigment paste. The shades are fast to light and are useful for poster papers. The presence of high proportions of lead rule out the possibility of these products being used in papers for food wrapping.

Ultramarines are used extensively for the tinting of whites and in the production of azure shades in the paper industry. Ultramarines are made by calcining mixtures of china clay, sodium sulphate, sodium carbonate, sulphur, silica and charcoal, the shade of blue obtained varying according to the proportions of the various ingredients used. They possess a very high order of fastness to light and alkalis but are destroyed by even dilute acids. In heavy shades they give markedly two-sided effects.

Carbon Blacks are not strictly inorganic in nature but may be included in this group of pigments. They consist essentially of carbon in a finely divided state and are marketed to the paper industry as readily dispersible powders or pastes. The shades possess maximum fastness to light and to various chemical treatments.

Organic Pigments. This range includes insoluble azo, phthalocyanine and anthraquinone pigments which give varying shades of maximum fastness to light and of very good fastness to acids, alkalis and water respectively. On account of their high cost their main use is in tinting and pale shades.

They are usually marketed in the form of pastes but there is now a growing tendency for manufacturers to supply them in the form of redispersible powders which can be added dry to the beater.

When using pigments of all types it is advisable to make the addition early in the beating to ensure that maximum colour value is obtained by the reduction in particle size arising from the addition of the beater roll.

Synthetic Soluble Dyestuffs. This class may be further sub-divided into Basic, Acid, Direct, Sulphur, Azoic; of these the sulphurs and azoics find very little use in paper-making and may be discounted.

(*a*) *Basic Dyestuffs.* As the name implies all these dyestuffs are organic bases and are marketed in the form of salts, usually the hydrochlorides. Examples are: Auramine, Methyl Violet, Methylene Blue, Rhodamine and Malachite Green. They are characterized by brilliancy of shade and high tinctorial power but possess a low order of light fastness.

By virtue of their properties Basic dyestuffs are most used on low grade and unbleached furnishes; for the lignin contained in the latter they possess a strong affinity. This affinity can lead to mottling or the production of silurian effects on mixed furnishes.

It should be noted that Basic dyestuffs which are soluble dyestuffs are precipitated by Acid or Direct type dyestuffs and when using them in admixture with these it is essential to dissolve and add to the beater separately; in this way the property of precipitation is used to advantage to obtain clearer backwaters.

When dissolving Basic dyestuffs care should be taken to ensure that the temperature of the water does not exceed 160° F., since difficulties due to 'tarring' are likely to arise if higher temperatures are employed. It is recommended that before adding the hot water the dyestuff should first be made into a smooth paste with a little cold water or acetic acid.

(*b*) *Acid Dyestuffs* are so named because the original use thereof was for the dyeing of wool from an acid bath. Chemically they may be generally described as sodium salts of sulphonic acids.

They have no affinity for cellulosic fibres such as are used in paper-making and require the presence of resin and alum for fixation on a beater furnish; in deep shades it will usually be found that an excess of size and alum is required to give reasonably clear backwaters.

In dissolving the acid dyestuffs it is recommended that a smooth paste be first obtained with a little cold water before adding boiling water. The solution should be added to the beater through a sieve.

A feature of the Acid dyestuffs which must be remembered is their tendency to 'burn' on the cylinders when dried at too high a temperature. This phenomenon takes the form of a surface mottling and usually arises in very deep shades or on heavy substance papers or boards where it is necessary

to run the dryers very hot. There is no remedy except running the cylinders at a lower temperature.

(*c*) *Direct or Substantive Dyestuffs.* The name is derived from the fact that these dyestuffs possess direct affinity for cellulose thus allowing their use in unsized as well as sized papers. In the case of the latter clear back-waters are obtained in all but very heavy shades, a distinct advantage over other soluble dyestuffs.

It is most important in the case of Direct dyestuffs that the dyestuff should be added before the resin and alum, otherwise not only will weak and/or dull shades be obtained, but the normal tendency of this type of dyestuff to mottle on bleached furnishes will be accentuated.

The recommendation for dissolving is, as in the case of the other soluble dyestuffs, first to paste with a little cold water and then to add hot water as required.

To avoid mottling it is advisable to add to the beater from as cool and dilute a solution as possible.

Variables in Paper Dyeing. Having described the types of dyestuff and their general properties it would be of advantage to discuss the variables which may arise in paper dyeing and the behaviour of each type of dyestuff with such variation. The variables are furnish, degree of sizing, degree of beating, order of addition of agents, and these will be discussed under the separate headings.

Furnish

Bleached Cellulose Fibres. Included in these are bleached sulphite, esparto, straw and rag pulps respectively.

Basic and acid dyestuffs have no natural affinity for these furnishes and good sizing is essential to obtain any colour-value under such conditions.

Direct dyestuffs, on the other hand, possess excellent affinity and may be applied with or without sizing agents. On this account they are particularly suitable for the dyeing of blottings and other unsized papers.

Pigments have no natural affinity and depend on the presence of sizing agents for any colour-value obtained on these furnishes.

Unbleached Furnishes. Examples are unbleached sulphite, unbleached kraft. Basic dyestuffs have an affinity for the lignin content of such furnishes and exhibit their maximum colouring power on this particular type of pulp.

Acid dyestuffs again have little or no affinity and are only satisfactorily applied in cases where good sizing with resin and aluminium sulphate is permissible.

Direct dyestuffs have affinity for the cellulosic portion of the furnish, but since these dyestuffs are in general dull in shade, the low colour of the ground precludes their use except in those cases where there is a particular demand for light or other fastness properties.

Pigments of all classes can only be used when the papers from these furnishes are sized since there is little or no retention without alum.

Mechanical Wood is a pulp consisting of a low-grade fibre with poor felting properties.

For the colouring of this furnish dyestuffs of the Basic class are very suitable in the case of sized and unsized dyeings, the non-cellulosic portion of the pulp appearing to act as a mordant. Mechanical wood pulp always contains, however, a proportion of shives which are often uncoloured or only lightly stained by Basic dyestuffs which are preferentially absorbed on the finer fibres.

Acid dyestuffs have no natural affinity for mechanical wood but most of them are adequately fixed by resin and aluminium sulphate, in which case the dyestuff is precipitated on the fibres as a complex lake ; and, in fact, they are often used on mixed furnishes containing mechanical wood on account of the levelness of the shades produced.

Direct dyestuffs have little or no affinity for mechanical wood due to the comparatively low proportion of cellulose.

The cheaper pigments—for example, Carbon Blacks, Van Dyck Browns, Prussian Blues, etc.—are widely used as combined colouring and loading materials but only when alum is present to help the retention.

Degree of Beating. It may be stated that with all types of dyestuff the higher the degree of beating of any particular stock the greater is the apparent depth of shade obtained.

Effect of Size and Alum. The part played by size and alum is important not only for the degree of sizing obtained but also for its effect on the retention of dyestuffs in paper-making systems.

Acid dyestuffs, as previously stated, depend entirely on these additions for their retention on any furnishes, and going from a lightly sized to a heavily sized stock will result in a much greater depth of shade.

Direct dyestuffs are little affected by changes in sizing conditions and this applies also to the Basic dyestuffs.

Pigments, on the other hand, are markedly affected particularly by increases in amount of alum used.

Attention should be drawn to the fact that particularly in the case of Direct dyestuffs the order of addition of the various reagents is of great

importance, and in most cases of this class the true shade is only obtained if the dyestuff is added before the resin and alum.

Addition of Fillers. The addition of china clay to a furnish can have a marked effect on the result obtained from the use of dyestuffs of all classes. In the first place there is the dilution effect which gives, of course, weaker tinctorial results and there is the brightening effect on the final shade. It should be remembered that individual dyestuffs have varying affinities for fillers such as china clay, and the differing affinities of respective dyestuffs in a recipe may have a decided effect on two-sidedness.

Matching Shades in the Mill. Having surveyed the various types of dyestuffs and taken note of their varying properties we are in a stronger position to make the right selection of dyestuffs for a particular paper.

This having been done the next important step is to consider the approach to matching on the machine.

Laboratory recipes obtained by the production of hand sheets at a consistency in line with that to be encountered on the machine can be a useful guide, particularly if care is taken to use identical furnish, water supply, sizing conditions, beating conditions and filler additions. Due to the poor backwaters obtained with Acid dyestuffs the correlation between laboratory and mill is less reliable with these dyestuffs than with any other.

It should be stressed that wherever possible the number of dyestuffs used for any one particular shade should not exceed three.

It is usual to furnish the beater with 20 per cent less dyestuff than the laboratory match calls for and after beating for a reasonable length of time a hand sample should be taken from the beater, drained under conditions as nearly approaching those on the wire as possible and then dried under comparable conditions with those to be followed in practice. If the run has been done previously comparison of wet stock should also be made. Any hand trials should be made if possible to the substance of the required paper and any special finishes should be imitated before comparing with the pattern to be matched. From these hand trials, adjustments may be made to the beater, and it should be made clear that any such adjustment should be carried out by altering the proportions of the original components and not by introducing further dyestuffs. Experience is the only teacher from whom the beaterman may gain his judgment as to the degree of his adjustments.

When a sheet representative of the stock in the chests comes over the machine a further adjustment may be necessary and there are two methods of effecting this. One is the addition of further dyestuff to the stuff chest, and the more satisfactory method is the use of compensating beaters.

In the former case a warning note should be struck in that if the recipe

contains Direct dyestuffs, shading at the stuff chest will amount to addition to prior sized stock, and from earlier remarks it will be gathered that the true shade and value of the dyestuff will not be obtained. If it is absolutely necessary to shade at this stage it will be advisable to deviate from the procedure laid down and increase the number of dyestuffs by the use of an Acid or Basic shading component.

If the dyestuffs used in the matching are not identical with those in the sample the light source when comparing the two patterns is of great importance. Specially designed lamps to approach daylight as nearly as possible should be used when matching on the night shift.

Colour Troubles in Paper Dyeing

Two-sidedness is a very complex problem of which there is little fundamental knowledge. It is generally accepted that it arises from the removal of more heavily dyed fines, pigment or coloured filler from the underside of the sheet by suction or by the washing effect of the water carried over by tube rolls, etc. Factors influencing the degree of two-sidedness are stock freeness, suction, machine speed and dyestuffs, but the manipulation and choice of the most satisfactory conditions depends entirely on the individual case and is not capable of generalization.

Dye Specks may usually be attributed to careless handling of the soluble dyestuff or pigment, and too much stress cannot be laid on careful dissolving of the former and adequate dispersion of the latter.

Dye Mottle may be produced by adding Basic or certain Direct dyestuffs dry to the beater or by the use of too hot and concentrated a solution of one of these types. It may usually be remedied by using cold dilute solutions of these products. The use of dispersing agents with Basic dyestuffs has also been found to be most effective in preventing mottling and by this means proves even economical.

Acid dyestuffs are particularly susceptible to burning, especially in heavy shades and in the case of wet beater stock where it is necessary to hold the drying cylinders at a high temperature. The only remedy lies in reduction in temperature of cylinders, which means the always unpopular slowing of the machine or use of Direct or Basic dyestuffs not susceptible to these conditions.

Shade variation can be particularly troublesome over a long run and may be attributed to one or more of a number of factors.

The first factor likely to cause variation particularly in pale shades is a difference in the colour of the furnish.

Secondly, there is a possible lack of uniformity in colouring procedure; for example, the idiosyncrasy of one beaterman as opposed to another may bring about a change in the order of addition of dyestuff, resin and alum; the beating may vary as also may the length of time between colouring and dropping the beater.

Then there may be a variation in pH which is particularly important in the case of Acid dyestuffs which are more susceptible to changes in this factor than members of the other dyestuff ranges.

The amount of active bleach left in half stuff can considerably alter the shade, particularly in the case of those dyestuffs which are almost completely destroyed by hypochlorite.

Alteration in the temperatures of the drying cylinders can produce most marked effects on the appearance of the dyed shade; Acid dyestuffs give a considerably deeper appearance due to the bringing of the dyestuff to the surface of the sheet, but the possible unevenness of the dyed surface may be most undesirable in these cases.

Surface colouring. All the previous observations have dealt with beater dyeing which probably represents at least 90 per cent of the whole of paper dyeing.

Calender staining is, however, employed to a limited extent and the main factor involving choice of dyestuff here is solubility.

Whilst some Basic dyestuffs do find use in this particular field the products most used are Acid dyestuffs on account of their good solubility.

Crêpe paper staining is also carried out mainly by the use of Acid dyestuffs and to a lesser extent with the more soluble of the Basic dyestuffs.

CHAPTER XIV

CLEANING OF PAPER STOCK AT THE MACHINE

No matter whether the paper that is being produced is a fine writing, a high-class printing paper or a common wrapper, it is important that it should be clean, and free from specks of foreign matter of all kinds. For this reason paper-makers have for years tried everything they could think of to eliminate what is commonly called dirt. The making of clean papers starts very far back in the mill, and in the case of rag papers actually in the rag room itself, where women are employed to sort the rags, cut off buttons, pins, fasteners and pick out contraries of all kinds, which, if they were allowed to go through the process, would result in specks of dirt in the finished paper.

At almost every stage in the paper-mill precautions are taken against dirt; for instance, in the washing engines there are sand-traps and button catchers and other contrivances to take out dirt or junk. Spotlessly clean floors and conditions in the mill are also very important; but it is when we have the stock almost ready for the paper-machine that the final efforts are made to remove all impurities and get the stock as clean as ever possible before it passes on to the paper-machine.

Most cleaning devices come between the paper-machine chests and the strainer at the end of the machine. For many years paper-makers had to rely on sand-traps, which were long troughs with felt nailed in the bottom, ladders of wood and depressions in the bottom of the trough, all arranged with the idea of trapping by gravity pieces of coal-dust, grit and small pieces of metal which are always being ground off beater bars, beater plates and refiner fillings. These sand-traps performed an extremely useful function, and got rid of most of the objectionable heavy materials, which would spoil and blemish the paper.

In the very early days there was also the machine strainer, which, at one time, consisted of a flat table with slotted plates which jogged up and down, and had wipers passing across the top to clean off the lumps and knots of fibre, and keep the strainer in such a condition that it would pass the stock required for the paper-machine. There are quite a number of these flat screens in use at the present time, and they are quite effective, especially in keeping back knots of uncleared fibres.

A great advance on this type of strainer was the introduction of the revolving strainer, or screen, such as the 'Wandel', the Watford 'Tremor',

and the 'Leith Walk' full-drum strainers. There were two distinct types of revolving strainer, those in which the stuff passed from the inside of the drum to the outside, and those in which the stuff had to find its way from the outside of the drum, through into the centre of the drum, and out at the end into the breast box. The latter, which was called the 'inward flow' type, was far the most satisfactory, and had the great advantage over the flat screen and the outward-flow strainer in that it was almost self-cleaning, and could, in fact, have the slot cleaned by sprays on that part of the strainer which was not in contact with the stuff. The design of these strainers is excellently shown in the illustrations (Figs. 93, 94, 95, 95A).

The introduction of these revolving-drum strainers led to a tremendous improvement in the quality of paper, for they not only kept back pieces of rubber and dirt, but they also kept back uncleared knots of fibre which would otherwise have got into the sheet, and this fact made for a very much improved appearance in the sheet of paper. The strainer plates which cover these drums may be obtained in a very wide variety of cuts, from very fine to very coarse, and generally speaking it is much better to have a fairly wide cut which will pass the stuff easily, than to try and force stuff through too narrow a slit. The ideal condition, of course, is to have ample strainers so that the smallest cuts possible for the length of fibre may be used, and the maximum elimination of dirt is obtained, and also the maximum number of clotted or knotted fibres are kept back.

CORRESPONDING GAUGES OF SLITS IN STRAINER PLATES

Watford, Bertrams' and Watson's	*Inch*	*Millimetre Gauge*	*Nearest Standard Wire Gauge*	*Watford, Bertrams' and Watson's*	*Inch*	*Millimetre Gauge*	*Nearest Standard Wire Gauge*
2	·006	·152	38	8	·030	·762	21
2½	·007	·177	37	8½	·032	·813	21
3	·008	·203	35	9	·035	·889	20
3½	·009	·228	34	9½	·037	·940	20
4	·011	·280	32	10	·040	1·016	19
4½	·013	·330	29	10½	·042	1·066	19
5	·017	·432	27	11	·045	1·143	18
5½	·020	·508	25	12	·050	1·270	18
6	·025	·635	23	13	·053	1·280	17
6½	·026	·660	22	14	·055	1·290	17
7	·027	·685	22	15	·058	1·300	17
7½	·028	·711	22	16	·062	1·580	16

The inward-flow revolving strainer is at the present time a very highly efficient machine, and has done a very great service to the paper trade.

About 30 years ago a further revolutionary type of paper stock cleaning machine was introduced from Germany. This machine, introduced by Messrs. Erkens, of Duren, was called the 'Erkensator', and a very large

number of them are in use at the present time. It works on the principle of centrifugal force, throwing out those particles of objectionable matter contained in the paper stock which have a higher specific gravity than cellulose. Erkens worked on the principle that whereas cellulose fibres and water had approximately the same specific gravity, most of the objectionable matter, which spoilt the appearance of paper, had a higher specific gravity and therefore could be removed from the flow of stock by centrifugal force. At the same time, he also attempted to remove those things which are lighter than cellulose, such as rubber. The Erkensator, which is illustrated, consists of a cast-iron base or stand in which revolves a phosphor bronze drum, which is built up in sections and has different diameters at the base and at the top. The stock to be cleaned passes down to the bottom of the drum, or basket, which is revolving at a high speed, and this speed causes the stuff to be thrown outwards and to climb up the inside of the drum wall. Here it meets various projections which trap the heavy particles, while the water and fibres still continue to climb up past these projections and eventually pass out at the discharge slit at the top. After the machine has been running for some time, and it is stopped, bolsters, or tight packed wads of fibre and loading, will be found to have been trapped behind the projections in the drum, or basket, and if these are examined they will be found to be full of pieces of metal, stone, coal and other impurities, which have been trapped in the soft pad of fibre and loading behind the projections on the drum. The Erkensator was so well designed in the first place that it has practically remained unaltered since it was first put on the market 30 years ago; and it is such an efficient cleaning machine that it will take out large quantities of shive, the specific gravity of which varies hardly at all from the fibres themselves, and this makes it an extremely valuable cleaning machine for paper stock where there is shive contained in the pulp.

There have been a number of other centrifugal machines developed and put on the market for paper-makers during the last 20 years, and many of these give the most excellent results. Some of them are much bigger in diameter, and have a greater capacity, than the Erkensator, and this is a very great advantage, as it means that a paper-machine need perhaps have only one or two centrifuges, whereas with the old original Erkensator it might be necessary to install six or seven to pass the same amount of stuff.

To get the best results from these machines they must not be overloaded, and the density of the stuff passing through should be as small as possible; ½ per cent in dealing with rag stock is not too little, and it even pays, in some cases, to pass the pulp through a thickener after it has been through a centrifuge where heavy papers are being made.

The Vickery 'Purifuge' is one of the best types at present in production in this country, and there is also another one made by Messrs. Broadbent, of Huddersfield, which has a very high capacity. Another machine with a big capacity is made by the Bird Machine Company, in America, and this machine gives excellent results.

Some of these machines for cleaning paper stock are described in detail in the chapter on the Paper-Machine. It is usual in most mills to bleed-off a certain amount of stuff from the bottom of the main strainer, and pass it into an auxiliary strainer. The purpose of this operation is to allow heavy stuff, which accumulates in the bottom of the strainer, and also knots, to be cleared away from the main strainer and dealt with separately, in order that the main strainer may not be clogged up, and in order to avoid having to shut the machine down to clean out the main strainer. This method of drawing stuff in a continuous stream from the bottom of the main strainer, and passing it through an auxiliary strainer, has many advantages: it enables knots of fibre, which might otherwise be lost, to be brought back into circulation; and at the same time it removes a lot of dirt, and keeps it entirely away from the clean fibre in the strainer. Generally speaking, this strained stock from the auxiliary strainer is passed back into the chest, and comes again into circulation.

Another method for dealing with the bleed-off, as it is called, from the main strainer, is to pass the stuff through a small high-speed refiner. This takes into account the fact that most of the stuff bled-off from the main strainer is lumps and knots of fibres, and thus, by passing these through a small high-speed refiner, they are cleared and rendered fit to go back into circulation by way of the machine chest. When these methods are adopted, there should be, and in fact there generally is, very little waste between the stuff coming from the beaters and what gets actually into the finished paper.

When rubber is troublesome this can be got rid of to a large extent by passing the stock through a rubber-catching box. This box receives the stock from the strainer, either as an overflow or from the bleed-off, and it is passed through a box with baffles, so that the stuff has to pass under one baffle plate and over the next. When this box is used it will be found that a great deal of rubber is trapped by flotation among the froth on the top of the box, and it is well worth while, when making fine paper from rags, to install one of these rubber-catching boxes in the circuit.

Many of the main machine strainers nowadays have the drum covered with plates made from stainless steel instead of the usual phosphor bronze which has been in use for many years. It is claimed that more stock can be passed through a stainless steel plate than can be passed through a similar

slot in a bronze plate. There is also the additional advantage that the stainless steel plates do not corrode so badly as the bronze plates.

In America it is very common to have the strainer drum hexagonal instead of round, as is the usual case in England. By having the drum formed of hexagonal plates, the plates may be flat, and it is not necessary to have them bent to make up the arc of the circle of the round revolving drum. These plates are cheaper to cut, and easier to fit, but they do not appear to have found much favour in England. The strainer drums are fitted, as a rule, into the strainer vat by means of felt-covered metal bands, which hold the drum in place, and make the seal between the drum and the vat. It is very necessary that these bands, and the felt covers covering them, should be carefully inspected at regular intervals, in order to ensure that there is a proper seal, otherwise lumps of fibre may pass through and be rubbed into hard knots, which are very objectionable when they find their way into the paper.

The forcing of a strainer to take more stuff than it is really capable of taking is one of the worse faults, and leads to a lot of dirt getting into the paper. Every care should be taken to see that the machineman never has too fast a stroke on the flappers, which cause the reflex action against the drum. It is also important that the flow of stuff into the strainer should be evenly spread across the whole face of the drum, and not, as is so often the case, all into one end, so that most of the stuff has to pass through a small section of the drum instead of being allowed to take its time and go through the whole width.

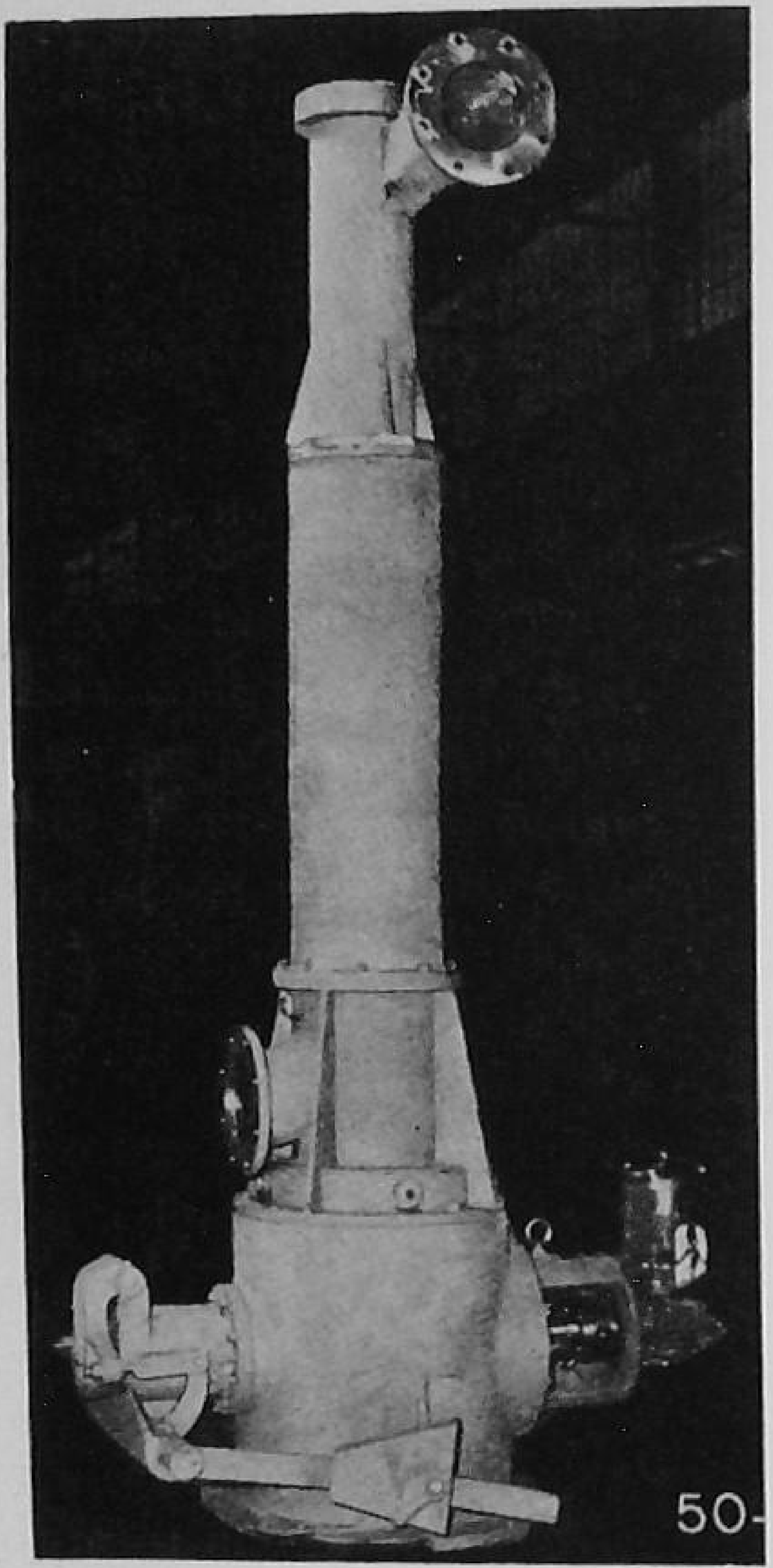
Another type of stock-cleaning equipment has recently been introduced by Shartle Brothers Machine Company. This works on the straight-through pattern from inlet to outlet, without any reversing of the flow. It is called a Hydraclone.

The stock enters the top of the unit tangentially under sufficient pressure (about 18 lb. per square inch) to produce the desired velocity to give centrifugal force. The consistency of the stock should be about 0·8 to 1 per cent to obtain good results.

As will be seen from the illustration (Fig. 73), the unit is complete in itself, standing on its own base, for mounting on the floor, or elsewhere, and it can be installed in a space of 6 feet by 3 feet, with headroom of 11 feet.

The incoming stock passes through the tangentially located rectangular opening into a stationary helix, which guides the stock in a controlled spiral where it is gradually accelerated by the increasing diameter of the central helix core. The increasing cross-section of the helix core accomplishes the delicate transition from pressure to velocity. The resulting laminar flow

permits particles having a higher specific gravity than water to be induced to the wall of the inlet casing by the centrifugal force which has been set up within the unit. It is claimed that the laminar flow obtained by the guided helix minimizes the interference factors which are always present in paper stock suspensions, allowing more efficient use of the centrifugal force available.



[*Shartle Bros. Machine Co., Middletown, Ohio*

Fig. 73.—Complete Hydraclone Unit for Centrifugal Cleaning of Paper Stock

The central core of the inlet helix deliberately forces all the stock off-centre and hence the particles in suspension are under the influence of centrifugal force all the time. The unit has no dead centre core, having a zero centrifugal force value, as the central solid core of the guided helix obviates this possibility.

As the stock spirals downwards to the point where the inlet casing joins the outer casing, the flow of the suspension actuated by centrifugal force has formed a definite pattern with the heavy particles concentrated against the wall of the inlet casing, while the clean stock is held in a layer against the central core.

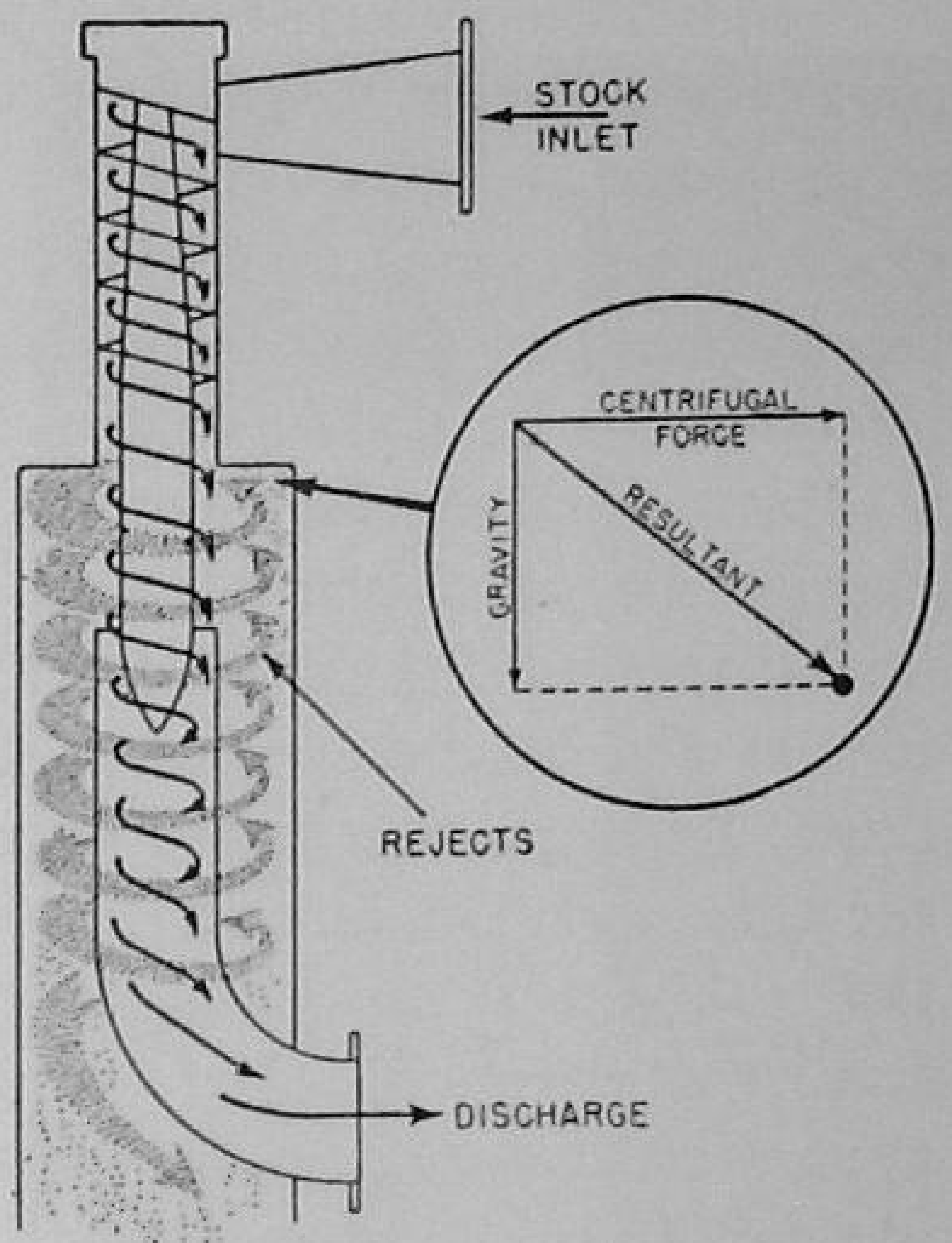
The suspension now enters a zone just below the point where the inlet casing is attached to the outer casing. The foreign particles which have been forced out to the wall of the inlet casing, are thrown out radially by centrifugal force against the wall of the annular outer casing.

The resulting path of the heavy particles is shown in the diagram (Fig. 74).

As the outer casing is completely filled with liquid, no radial movement of the entering liquid occurs, and the spiral rotation of the cleaned stock continues during its passage across the annular orifice.

An interface is thus formed between the entering stock and the water already in the outer casing. This induces the water in the outer casing to rotate in a secondary spiral flow. In this way turbulence at the interface is kept to a minimum, and the particles of high specific gravity can be readily

thrown, by centrifugal force, from the entering stream of stock into the outer strata of water. The centrifugal force induced here is sufficient to hold these particles against the outer wall, while gravity induces them downward, until they come to rest in the ejection chamber at the bottom.



[Shartle Bros. Machine Co., Middletown, Ohio

Fig. 74.—Diagram of the Hydraclone, showing Path taken by Heavy Particles thrown out from the Stuff

Meantime, the cleaned stock, still swirling, has entered the open upper end of the discharge tube, and passes out through an elbow at the lower end.

Once the grit and heavy particles have been centrifuged from the stream of stock, the discharge tube forms a solid wall and thus there can be no subsequent mixing of clean stock and the rejects. Separation of the foreign matter and grit is greatly helped by the inward flow of a stream of water which is kept at a low volumetric rate, slightly in excess of the volumetric displacement of the rejected material. This water is introduced through a control valve at a point just above the reject screw. The quantity is about 2 gallons per minute.

This water, called the elutriation water, also provides a back pressure across the discharge tube, which induces the clean stock to maintain its desired course by forming a liquid lock at this point. This incoming water also back washes any paper stock particles which have been carried down to the reject chamber by becoming attached to heavier particles of rejected material.

The large 1,000 gallon per minute unit requires about 15 h.p., more or less, according to the location of the unit.

The *Vortrap* employs the multiplication of gravity effect by means of centrifugal force, requires but little attendance, makes possible a very compact layout and permits continuous and uniform operation 24 hours a day without disturbing in any way the operation of the paper-machine.

Essentially the vortrap consists of a long cylindrical pipe within which a liquid suspension is made to revolve very rapidly. The swirl is produced by forcing the suspension under pressure into the top of the cylinder through a tapered tangential inlet. It then travels downward at high velocity along a helical path, until it reaches the bottom, where it reverses to return along the

central axis to the outlet trumpet, which is located near the cylinder's top, but below the tangential inlet.

The momentum of the incoming stream keeps it moving downward along the cylinder wall as long as it has a free path, allowing the axial region, as projected below the outlet pipe, to remain relatively undisturbed. This results in the formation of two distinct concentric regions within the cylinder; one adjacent to the wall in which the suspension is moving downward, and the other as a central core in which the suspension is moving helically upward.

Two diaphragms, each having a central aperture, are provided in the cylinders of the vortrap. One is located between the central flanges and one at the bottom of the lower cylinder. Below the bottom diaphragm is a funnel-shaped end piece, or cone, connected by piping to a suitable container for collection of the separated dirt. The tube or piping connecting the cone with the dirt receiver is provided with a valve and a sight glass so that the dirt passing downward can be observed. The dirt received can readily be emptied, as required, without interfering with the operation of the apparatus. Special arrangements are employed for the continuous ejection of solids from the base of the vortrap.

The rapid rotary motion within the cylinder produces a force which acts upon the suspension as a whole to produce a pressure difference and also acts on the individual particles in proportion to their mass and specific gravity. Since the angular acceleration is very much greater than the acceleration produced by gravity alone, the force produced can be used to effect the separation of very fine particles of solid matter from a liquid whose specific gravity is only slightly less, and to separate from one another particles of different specific gravity or form, also removing one type while leaving the other in suspension.

Thus, the apparatus is successfully applied to the separation of dirt from pulp suspension, the long wood fibres whose weight is very nearly equal to that of the water being kept in suspension, while the sand, scale and similar dirt are removed. Furthermore, there is removed a certain proportion of dirt specks comprising bits of bark, sawdust, pitch, etc., whose weight corresponds very closely to the fibres themselves. The ability of the vortrap to do this is attributed to the difference in form of these particles which permits them to move through the suspension more readily than wood fibres.

Vortraps are manufactured in five different sizes. These are the $1\frac{1}{2}$, 3, 4, 8 and 10-inch sizes, which dimensions apply to the diameter of the cylinders of the vortraps. Maximum g.p.m. for efficient operation of the different sizes of vortraps indicated are 20, 105, 235, 750 and 1,000 g.p.m. each, respectively.

Vortraps may be used in many different applications and each installation should be considered on the basis of the final results desired.

Normally for fine grade papers the 4-inch vortraps are considered preferable on the basis of their high efficiency in cleaning these stocks. Provided there are no special static head conditions to overcome at the vortrap outlet, an inlet pressure of 25 p.s.i. with an 18 to 20 p.s.i. pressure drop is recommended for this and smaller vortraps for a single unit installation. For an installation of two or more vortraps in parallel, a pressure inlet of 28 to 30 p.s.i. with a 22 to 25 p.s.i. drop in pressure between the inlet and outlet headers is recommended. These indicated pressures will give an average volume of 190 g.p.m. through each 4-inch vortrap. For an approximate check of 4-inch vortrap capacity, a single unit will handle approximately 1 ton of airdry stock per 24 hours for each one-tenth of 1 per cent consistency.

The larger vortraps (8-inch and 10-inch sizes) are considered for large volumes of stock or slurries where the primary purpose is the removal of sand, grit and similar heavy particles in relatively large quantities. Typical examples arise in the initial cleaning of stock in pulp mills, de-inked stock and paper board filler stock systems. These vortraps are usually low pressure units. Generally, unless there are particular static head conditions to overcome at the vortrap outlet, an inlet pressure of 15 p.s.i. with a 12 p.s.i. pressure drop is recommended. These conditions allow a 1,000 g.p.m. capacity for the 10-inch unit and a 650 g.p.m. capacity for the 8-inch vortrap.

In general, the lower the consistency of the stock in the vortrap system, the greater the dirt removal efficiency, particularly as regards the removal of the lighter foreign particles. For best efficiencies on average stocks, consistencies of 1 per cent or preferably less are recommended, but 1.4 per cent should be the maximum. The freeness of the stock has little effect on stock-cleaning efficiencies.

Pressure drops through the vortrap in excess of those recommended above will result in a gradual decrease in efficiency, though the upper limit thus established is not as critical as the lower limit. The pressure drop is also an indication of volume of liquid being passed through the vortrap. Principles of recirculation are employed to allow for any required volume change to process and to balance the vortrap system.

Total required capacity is obtained by the use of a multiplicity of these units connected to common inlet and outlet manifolds.

The vortrap is illustrated in Figs. 89 and 90, pp. 229 and 231.

CHAPTER XV

THE FOURDRINIER MACHINE

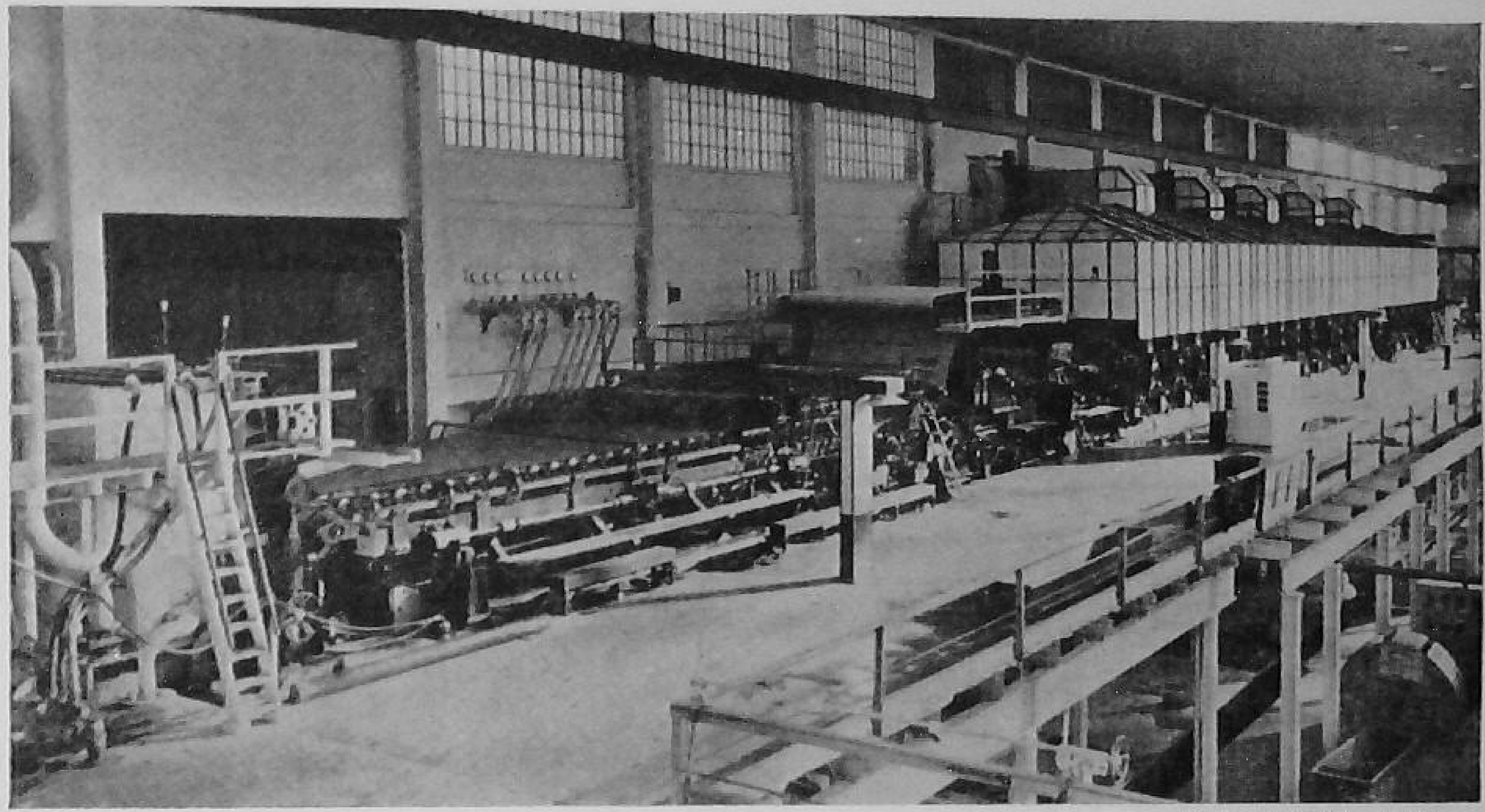
The modern paper-making machine is a very complicated affair, and gets more complicated almost every year, as new ideas are incorporated. We will not in this chapter go into the subject of any specially built machine such as the huge machines that are designed to make newsprint at speeds of up to 2,000 feet per minute (see Chapter XXI) or the special machines for making tissues at over 2,000 feet per minute. We propose to confine our remarks to the usual type of Fourdrinier capable of making a wide range of papers from wood pulp alone, wood pulp and rags, esparto, straw or any of these fibres in any combination (cf. Fig. 75, folder).

The machine actually begins at the stuff chest (Fig. 76), and it is here that the stuff prepared in the beaters is handed over to the control of the machineman. Stuff chests are constructed in sizes varying according to the output of the beaters and the machine itself, and they may be either circular or oblong, and made from concrete, cast iron or wood. For a general purpose machine, say 100 inches wide, and running with the above-mentioned furnishes at speeds of up to 500 feet a minute, a chest holding 2 tons of stuff, dry weight, is a very convenient size. Two chests are essential, but it is much better if three can be provided. They should be set so that the bottoms are above floor level, or at least above the level of a convenient drain, so that they may be washed out when necessary. Their dimensions may be such as are most convenient—deep and narrow, or shallow and wide. The bottoms should be concave with all edges bevelled, with the pipe leading to the stuff pump connected as low as possible, and a waste valve in the bottom. This ensures that when the chest is to be emptied and washed out, no stuff will be left where the pump cannot get it. It is very important that the last pound of stuff should be taken up and over the machine. Where there are many changes of colour, etc., a very great loss may easily occur if this point is neglected.

The chests should be lined with glazed tiles, copper or lead, or with cement with a highly glazed finish.

The best method of operating the chests is to use one chest for emptying the stuff from the beaters and diluting it to the consistency required for passing it through the refiners, if these are used. This may be anything from 2 to 4 per cent. The stuff is then pumped out of the emptying chest, through the refiner and into one or other of the machine chests.

The two machine chests should be connected together by means of connecting pipe and valve, and stock from the refiner should pass into one



[Walmsleys (Bury) Ltd.

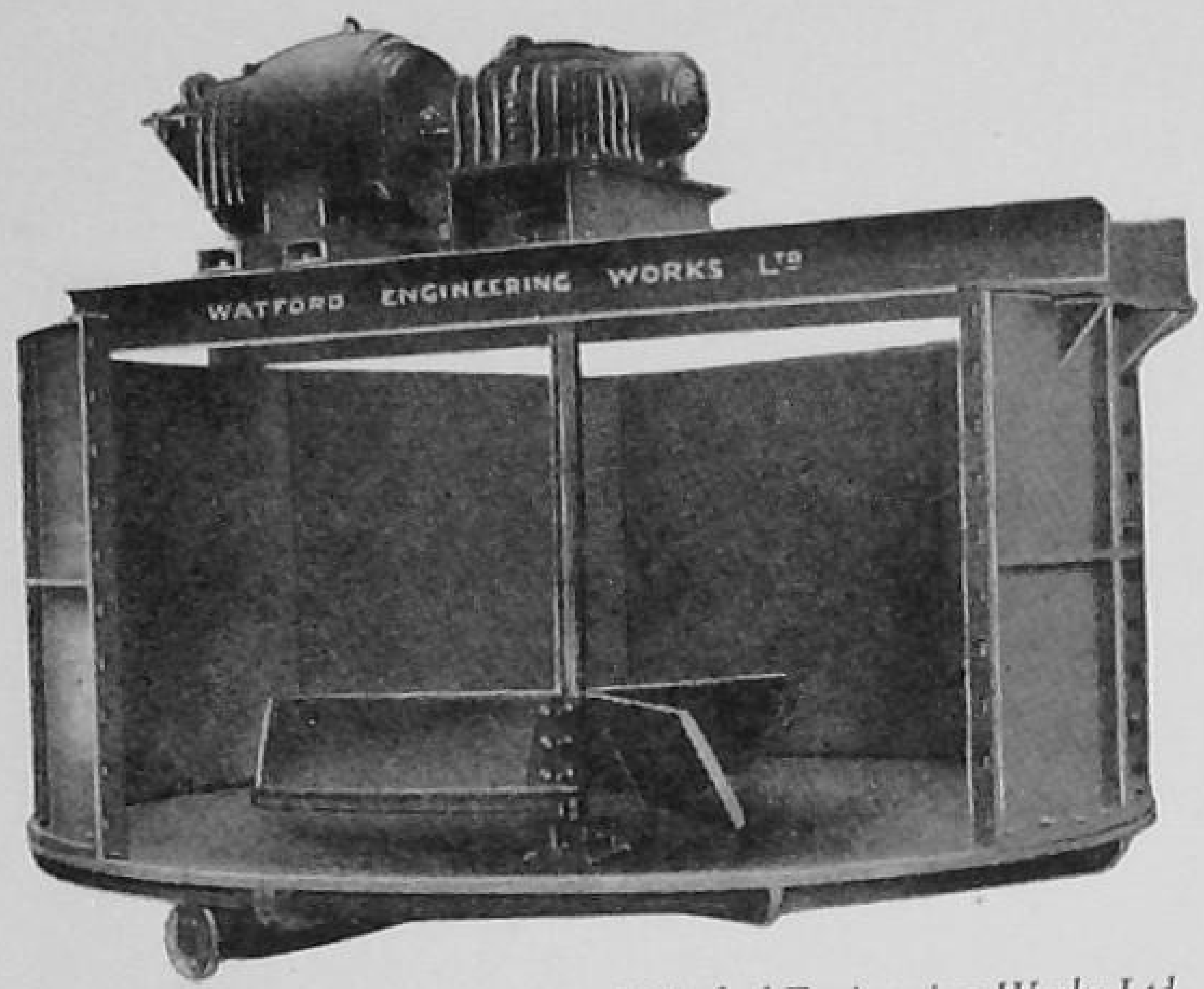
FIG. 75A.—120 IN. TRIM MACHINE FOR THE MAKING OF MACHINE-COATED PAPERS
The individual suction box control system is clearly shown beyond the wire.

chest, in which it may have to be diluted, and from there find its way through to the machine chest in order that the greatest regularity in weight may be made possible for the machine.

When the machine is stopped longer than usual for any reason, the chest may be filled with stuff which may be circulated by pump through the connecting pipe, thus ensuring a large quantity of stuff of the same consistency and shade being available when the machine starts up. Some of the older mills are compelled to work the stuff almost as it is put down from the beaters, owing to the chests being too small to hold a reasonable quantity to give regular consistency; then colour, consistency, and quality of the beating may change with each beater. This occasions a great deal of trouble with 'shades' and 'weights' in making, as all of these may alter several times in one shift.

Where a refining engine is used, the chest from which it works should be about 30 cwt. capacity, and kept well filled with stuff. Then, as the beaters are put down, the change in colour, etc., if it does happen, does so gradually, and the machineman and colourman can make correction before it gets far off the sample. In the same way, if the machine is provided with chests that are too small, by emptying the stuff into one chest and letting it come gradually

through the connecting pipe to the other, from which stuff is being worked, the chances of rapid change in weight and shade are somewhat lessened.

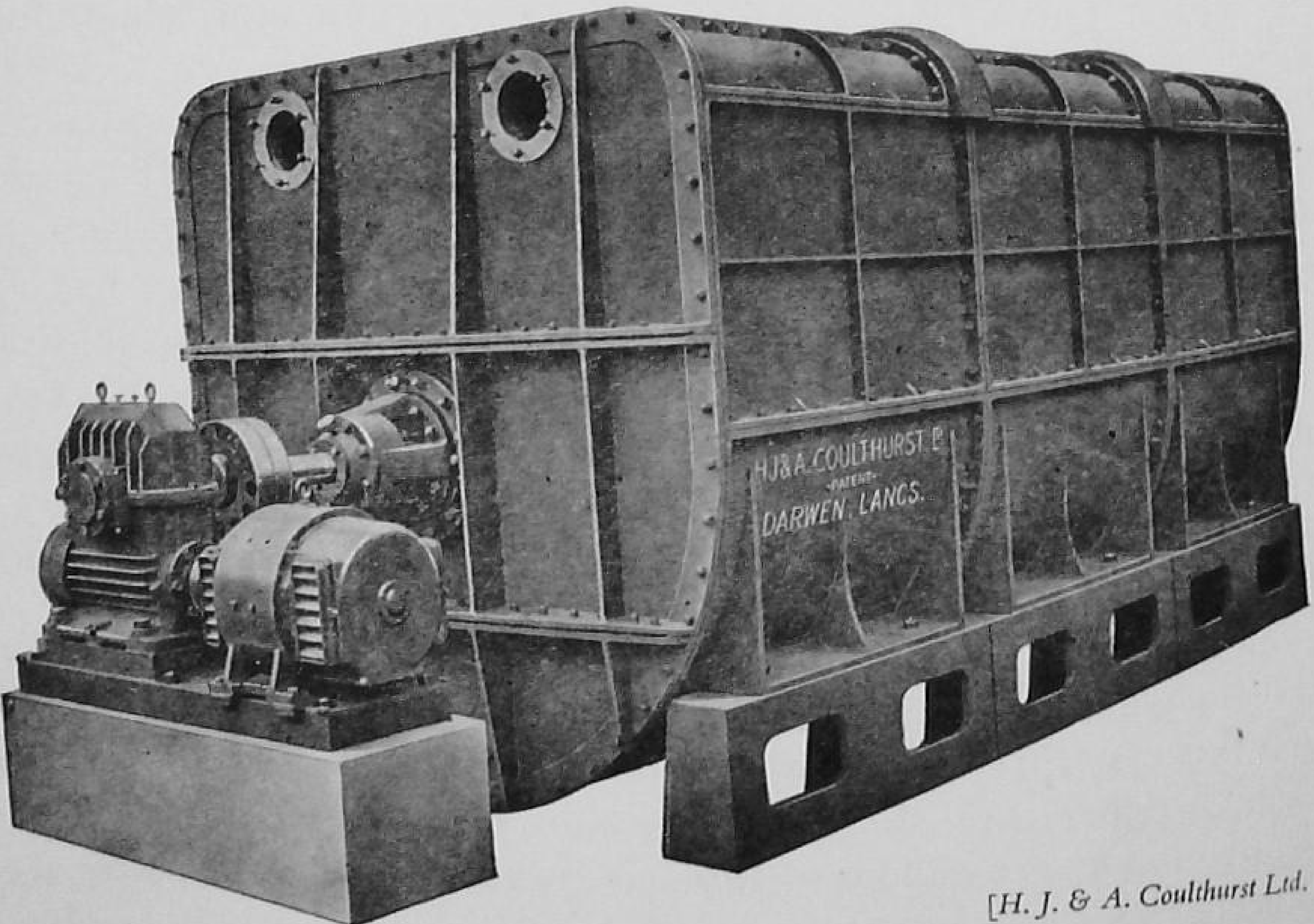


[*Watford Engineering Works Ltd.*

FIG. 75B.—MACHINE STUFF CHEST OR MIXING CHEST FITTED WITH DIRECT-COUPLED AGITATOR GEAR AND IMPELLER TYPE AGITATOR

It is, however, the worst policy for a mill making 'fine' papers from rags and mixed furnishes to have to do this, for no matter how skilled the beatermen may be, irregularities in making (weights and especially shade) must always occur. Also, as no two beatermen treat their stuff in the same degree as to length, wetness and even the quantity of water they let down with the beaters, there are bound to be at least three upsets in colour, make and weight every 24 hours.

If considered necessary a consistency regulator may be placed between the refiner and the machine chests, with a suitable regulating box; or the



[*H. J. & A. Coulthurst Ltd.*

FIG. 76.—COULTHURST HORIZONTAL TOTALLY-ENCLOSED STUFF CHEST WITH MOTOR AND REDUCING GEAR FOR AGITATORS

consistency regulator may be arranged after the high level box to regulate the actual stuff passing to the paper-machine after dilution.

The Consistency Regulator

There are many of these regulators available to paper-makers, and a great deal of controversy for and against the various designs. They all work on the same principle, which depends upon the regulator being able to determine any change in the viscosity of the pulp if the consistency changes during the passage of the pulp through the regulator, and then being able automatically to add more water to the pulp if the density becomes too thick. With the Trimby consistency regulator, control of densities between 1 and 5 per cent may be achieved with a maximum variation of 0·1 of 1 per cent, plus or minus.

Consistency regulation is automatic, is not dependent on the tonnage handled and is suitable for use with centrifugal pumps. The basic principle used is the change in friction head with consistency changes; this change engages a fork and ratchet mechanism controlling a water valve. The dilution water is admitted at the pump suction and mixed with the entire volume.

The regulator should be located directly over the stuff chest, and its supply line should be free from sharp bends.

The Sall Regulator consists of an indicator with impulse transferrer and a regulating device. The indicator regulates consistency of stuff by adding water in sufficient quantity to the stuff before it reaches the regulator. The standard indicator consists of a float device placed in an indicator box. This box takes the whole quantity of the stuff, or part of it. The illustration (Fig. 77) shows the design of the indicator box frequently used to keep the stuff on paper-machines at a regular consistency. This type of indicator box is used where the consistency of the stuff has to be regulated from 1·5 per cent to 4 per cent. For stuff of lower or of very high density, other types of indicators are used.

As will be seen in the illustration, the control takes place between a stuff chest and the paper-machine, where the stuff is being pumped from the stuff chest. In this case the whole quantity passes through the indicator box, the size of which depends on the amount of stuff being used per minute. For instance, for about 275 gallons of stuff per minute, the box would be about 4 feet 7 inches by 2 feet by 3 feet.

The stuff first passes the inlet compartment (2), which is connected with the level compartment (12), from where part of the stuff passes through the

outlet (3) to the float compartment (4). By means of a balance (7) and rods (8 and 9) the float is connected with a movable guide (10) fixed to the

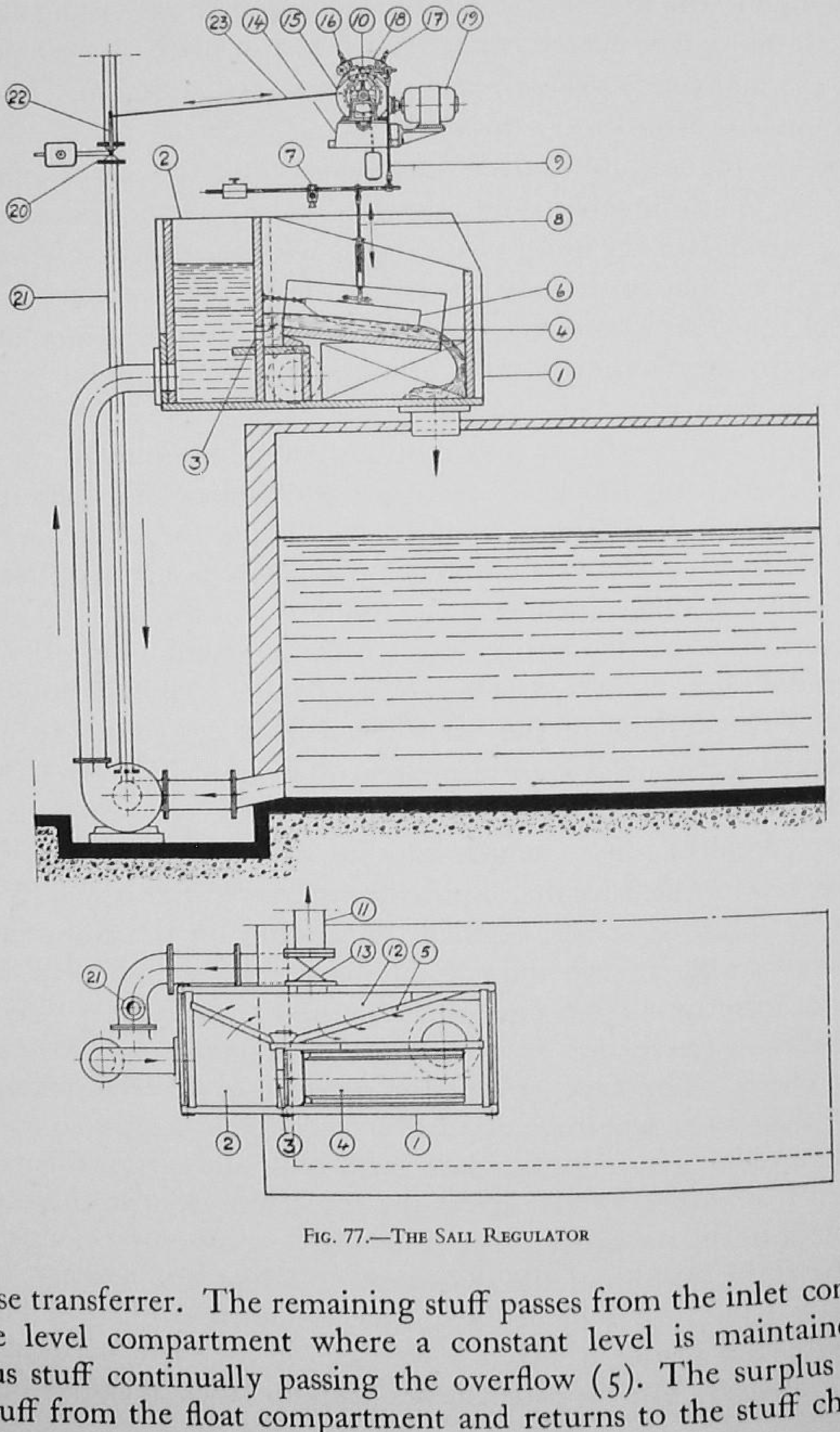


Fig. 77.—The Sall Regulator

impulse transferrer. The remaining stuff passes from the inlet compartment to the level compartment where a constant level is maintained by the surplus stuff continually passing the overflow (5). The surplus stuff joins the stuff from the float compartment and returns to the stuff chest. From

the level compartment the stuff is let out through the pipe line (11) to the machine. Since the consistency of the stuff and the pressure in the level compartment are kept constant, a uniform quantity of stuff will pass through the pipe line to the machine at a certain position of the valve (13).

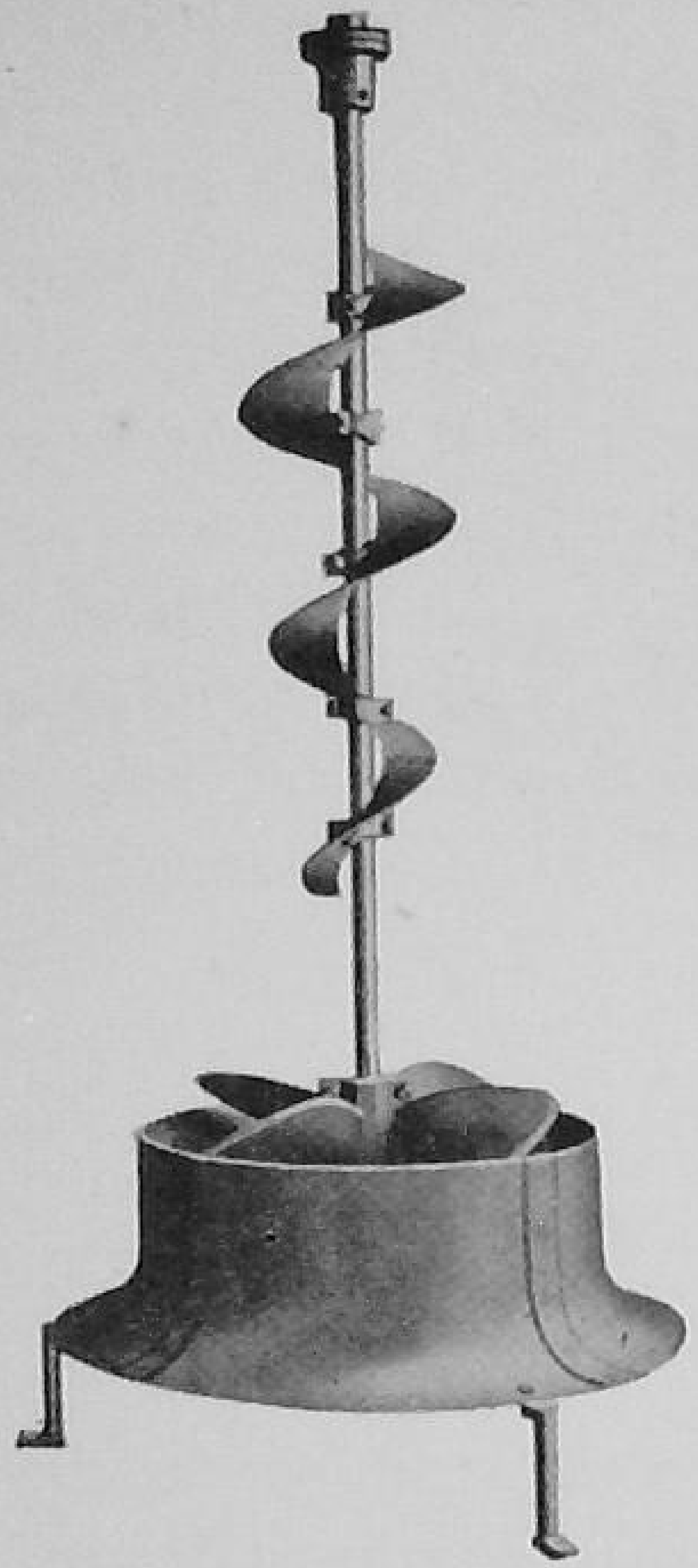
The impulse transferrer (14) is composed in main of a friction grooved wheel (15) and two pawls (16 and 17) of a special design. The pawls are fixed by means of links to a movable rod (18) driven by an electric motor connected to the impulse transferrer, the speed of the motor being reduced by a gear. The movable guide (10), which is connected to the impulse device, controls the engaging of the pawls with the grooved wheel. As soon as one or the other of the pawls engages the grooved wheel, the regulating device, in this case a butterfly valve (20), reacts to this movement, it being connected to the friction clutch belonging to the impulse transferrer by means of a chain wheel and chain.

The impulse transferrer and motor should be mounted on a common soleplate, carried on brackets, or on a wooden floor of 2-inch thick planks which can be placed above, alongside or under the indicator box. The impulse transferrer which is chiefly of phosphor-bronze requires a space of 20 inches by 20 inches including the motor.

In most cases the regulating device is composed of a butterfly valve (20) of a special design connected between two flanges in the diluting water-pipe line (21). The spindle of the valve has a lever (22) fixed to it, which is connected to the impulse transferrer by means of a chain (23). Where it is not suitable to draw the diluting water-pipe line to the regulator, the chain is connected with a wire which can be drawn over pulleys if wanted. The valve is controlled by the impulse transferrer so that a smaller or greater quantity of diluting water is added, depending on the consistency of the unregulated stuff. In the illustration the controlled quantity of diluting water is let into the suction pipe of the pump.

Agitators.—There are several types of agitators or stirrers used in machine chests. The type of agitator depends to a certain extent on the shape of the chest, whether circular or rectangular, and also on the stock itself. The older gate type agitator, with cross and diagonal bars of wood, suspended from a beam fixed across the top of the circular chest, is rapidly giving place to the propeller type. This stirrer consists of a shaft suspended in the chest; the bottom of the shaft rests on a foot step bearing. Near the bottom is fixed a 2- or 3-bladed propeller, as shown in Fig. 78. Sometimes smaller propeller blades are fixed at intervals on the shaft, but usually those are not necessary. The propeller blades keep the stock in agitation, and also

they thoroughly mix it, so that if it should be necessary to add any dye to the stuff in the chest, the mixing is thorough and very quick (Fig. 78).



[*Noble & Wood Machine Co., Hoosick Falls, N.Y.*

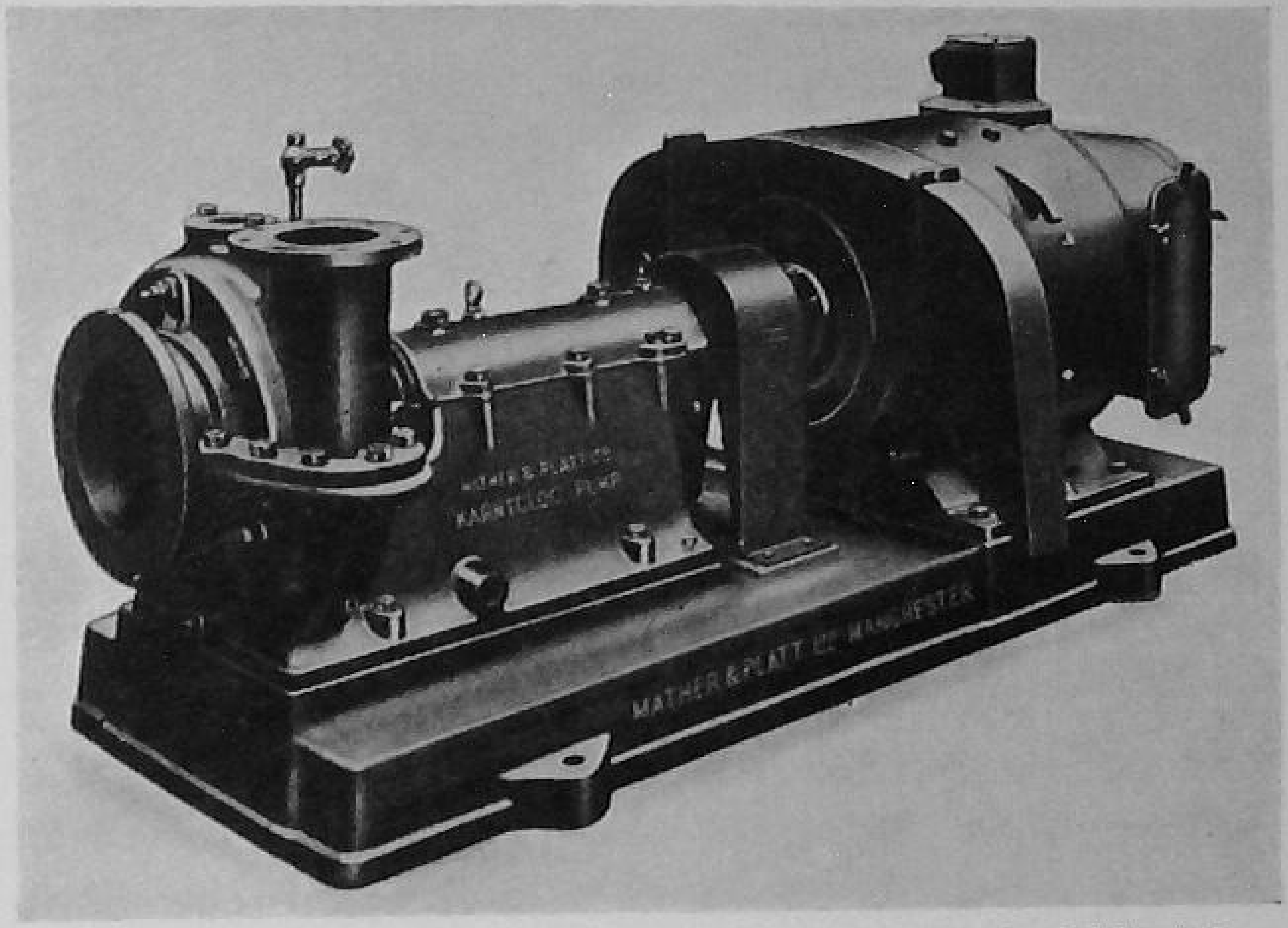
FIG. 78.—STUFF MIXER AND AGITATOR

The circulation and movement of the stuff may be observed when colour is added. Put in at the side of the chest, it travels round in a spiral streak until it reaches the centre, when it is seen to disappear downwards. Therefore, besides the travel of the stuff round the chest, it is being thrown up from the centre bottom to the top sides, and from there round, inwards and down to the bottom again. It is very important that, where esparto fibre is used, the agitators should be run slowly, otherwise the fibre will be rolled into little knots or balls. As efficient stirring is absolutely essential for the mixing of colour, loading, etc., it may be necessary to have two additional wings or blades half-way up the centre shaft to keep a full chest properly mixed. The top of the chests should be covered and made water-tight, leaving only a manhole with a properly fitted lid or cover. Generally, the agitator shaft is driven by bevel wheels on the top, and proper precautions must be taken to prevent grease, oil, or dirty water from finding their way down the shaft or through the opening left for the shaft. This may be accomplished by having a disc of metal running over the opening. Another, shaped like an inverted umbrella, may be bolted on the shaft close inside the top, and cleaned out every time an opportunity occurs. Though a rinse out with the hose-pipe is sufficient in washing out a chest on most occasions, all chests should be thoroughly cleaned and brushed at every opportunity.

The Stuff Pump.—There are two kinds of stuff pump in general use, the plunger pump with lifting valves, and the centrifugal pump. Nowadays the centrifugal pump seems to be ousting the plunger pump for pumping all kinds of paper stock, although many plunger pumps are still in use after 50 or 60 years, and still giving excellent service (Fig. 79).

A badly fitting or dry plunger or barrel will roll up the fibres, and for this reason it is necessary to have a jet of water constantly playing on the barrel of the pump and washing off little bits of fibre that may come up with each lift. The centrifugal pump has none of these faults. Indeed, the action of the swiftly moving blades has a certain clearing effect with badly

cleared stuff. There are no leather or other moving valves to get out of order. By regulating the chest pipe gate the pump may be made to supply



[Mather & Platt Ltd.

FIG. 79.—'KARTCLOG' STUFF PUMP FOR HIGH DENSITY AND LONG FIBRED STOCK

more or less, as desired, and to keep a good level in the stuff box as the level of the stuff in the chest goes down; and if, as is usual, it is direct driven, it occupies very little space, and its simple construction ensures cleanliness and few breakdowns.

The pipes from the chests to the stuff pump and thence to the high level stuff box or head box do not as a rule get very dirty, but a scrub out regularly is necessary to get rid of bits of metal, such as chips from the bars of the beaters, as these sometimes collect in the lower levels, and at certain times of the year slime may also be inclined to form.

The stuff box should be situated where it can easily be got at for cleaning purposes, and in such a position that the machineman can reach it in the shortest time, as it is often necessary to shut off stuff in a hurry. Very often large elaborate stuff boxes are provided, but this is not really necessary; all that is required is a box about 3 feet deep and 3 feet wide, either tile- or copper-lined. The box simply needs to be big enough to take the full amount of stuff required at the stuff tap, plus an overflow back into the chest, and the pump will be arranged to give this. The overflow from the box should be wide so that there will not be a great change in the level of the stuff with any possible variations in the delivery from the stuff pump.

The overflow chute runs to the chest, usually having a slide or gate to

direct the stuff to either of the two chests. The whole box and overflow pipes or chutes need frequent cleaning. The waste valve of the stuff box should be replaced carefully, and examined by the machineman after cleaning before he starts to pump up stuff.

The Stuff Gate or Stuff Tap.—This important valve is not apparently considered worthy of much attention by the engineers who fit up our machines. It is too often just a valve opened by a rough-threaded screw and without any gauge attached for the machineman's guidance. Those men who run machines making fine papers, where there are many changes, would appreciate a valve opened by a micrometer screw, with a good gauge, showing clearly the difference made by the slightest alteration. A record of makings can then be kept by the machineman with the approximate readings of the stuff gate gauge. This, of course, will not give the correct position for weight, speed, breadth, etc., from one making to the next, but if carefully kept will be of very great assistance in giving the machineman a good idea of what he may put on for a start. As no machine is immune from stoppage through foreign substances or clumps of uncleared fibres coming through, or not coming through the openings of the stuff gate, provision should be made for a quick and full opening to clear away the obstruction.

It is important that the stuff gate should always be worked as wide as possible to lessen this risk. Thin papers, of course, require a small opening, but the beaterman and machineman should have a settled consistency for thick and thin papers worked in conjunction with a written record. In this way a paper that normally would require a small opening would be put down with more water from the beaters and the stuff cock could then be further opened up. The very little trouble required to keep a record of stuff-gate opening is very amply repaid by the smarter working of the machine, quicker and more accurate changing of sorts and less broke. Where two chests of the same size are worked, the consistency of the stuff, which just means weight per ream, may be kept practically constant by careful filling to the same level. Various devices have been tried, worked by the density or consistency of the stuff for regulating and keeping steady weight. But this is one of the many points in paper-making where human skill cannot be replaced entirely by automatic means. While several firms have produced many types of consistency regulators, none of these has proved entirely satisfactory for all kinds of paper. The very fact that there are so many varieties of these regulators on the market, and that new ones are always coming out, seems to confirm this. A point that is worth noting is that fine stuff requires less opening than long stuff for the same weight per ream, and heavily loaded stuff less than unloaded.

It is remarkable that remote controls for stuff and water gates are not standard equipment in every paper-mill.

As these gates are usually in an elevated position by the head box, much time and effort is wasted by the machineman when making changes. When it is considered that until he makes an adjustment, the paper may be the wrong weight, or otherwise badly made, with too much or too little water, the small expenditure involved in fitting controls which operate at the front of the wire is soon recovered.

The mixing box is where the thick stock from the head box is diluted with white-water or, when starting up, with fresh water, to give the machineman the proper consistency of stuff to run paper of the desired weight on the paper-machine, and it is an important part of the equipment of the machine. It does not need to be very big, but it should be in a position easily accessible to the machineman, as if anything goes wrong he has to come here first to shut off the stuff and water.

The best type of box is a round one about 3 feet deep and 3 feet in diameter, with the stuff tap delivering stuff straight into it directed towards the bottom, and with the white-water tap directing the water tangentially against the side of the box. In this way the stuff is diluted evenly and quickly to the desired consistency, and overflows to the paper-machine evenly and steadily from a wide outlet. The box must be big enough to take the amount of stuff required when the machine is making its greatest output, without the stuff running over or splashing over on to the floor.

When shutting down at the week-end, or for any length of time, the best way is to run a chest empty. The hose-pipe may then be run into the chest, or the beaterman may put down a flush of water and clear the stuff through the pipe and pump, and run it over the machine. In any case, when running out a chest and changing colours, when it is necessary to shut and wash up, the pipes, pump, stuff box, etc., should always be emptied, and all the fibre possible run over the wire. The fibre recovered in this way may be run up the press and taken back to the beating room.

It will be found extremely convenient if a water valve can be placed in the stuff pipe immediately after the stuff valve leading from the chest. The chest valve can be shut off, water turned on and the stuff pump kept running until all the stuff has been completely pumped out of the system right through to the machine, where it may be either run up the presses and taken back as wet broke, or run down into the pit and pumped back into the white-water system, or for recovery. Every effort should be made to ensure that no stuff is allowed to run to waste under any circumstances.

The White- or Back-water System (Fig. 80).—It is possible, on most paper-machines, to recover almost the whole of the water which is removed from

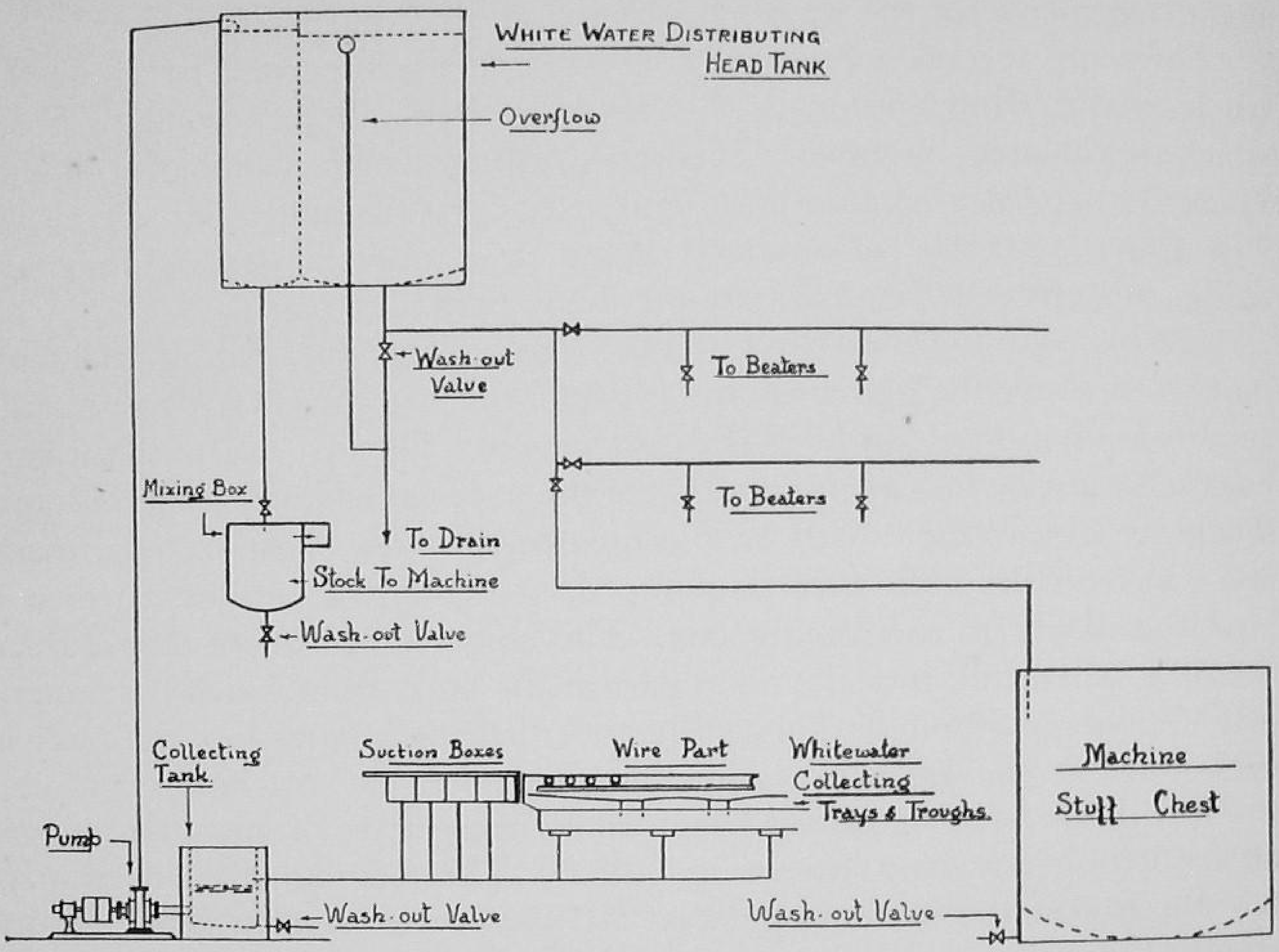


Fig. 80.—A Back-water System of a Paper-machine

In this diagram are shown the essential parts of a back-water system of a paper-machine. All water collected at the wet end is pumped up to a distributing head tank, which is divided off by a partition. The white-water from the smallest compartment returns to the mixing box, and keeps the machine supplied constantly. Any excess overflows into the large compartment of the head tank, and is distributed as shown in the diagram.

the stock at the wet end, as the sheet is being formed on the wire. It is extremely important that every care should be taken to save the whole of this water for immediate re-use. First of all there is the water which drains through the wire into trays and thence to the white-water pit, from which it is pumped to the white-water head tank, from which it is in turn used first for diluting the stock at the stuff tap, and secondly for emptying the beaters. Further than this there is water removed at the suction boxes, and also spray water used on the wire on its return. In many mills all this water may be lumped together and used for the dilution of stock in the stuff box, and for emptying beaters, without there being any likelihood of trouble. In some fine mills, however, it may be found more satisfactory to re-use on the paper-machine and at the beaters only that water which has drained through the

wire into the trays, in which case this water must be kept separate, and all other water from the wire pit may be pumped back and used in the preparation departments for the washing of rags and other purposes.

There are several reasons why it is extremely important to re-use the whole of the 'white' water, as this water is often called; it contains fibres which are valuable. Secondly, it contains loadings which are also of economic value. It may also contain alum and size, dyestuffs and other chemicals. The re-use of all this back-water very much reduces the demand for dyes, sizing, etc., after the original start-up of any particular paper.

The best way to re-use this water is to have a large distributing head tank raised well above the highest point at which the water may have to be used, and this is often found to be in the beater room. The first call on this water, however, must be for the mixing box of the paper-machine, so that this tank should be constructed with two compartments, one small compartment into which all the back-water is pumped, and from the bottom of which a pipe leads direct to the mixing box. This small compartment should then overflow, when full, into the main part of the tank, from which the beaters may draw their supplies. This will ensure that the mixing box can receive back-water at the earliest possible moment after the machine starts up, and it will also have a constant head supply irrespective of quantities drawn off for letting down or furnishing beaters. The diagram explains clearly how the back-water system operates. All back-water systems should be so arranged that they can be easily cleaned out, and the pipes rodded through and flushed out with water when this is necessary.

The system operates as follows: When the machine is started up, fresh water is turned on to dilute stock coming from the stuff gate to give the required dilution for the working of the stuff on the wire until it can be replaced by back-water. The water tap and stuff gate having been opened to the estimated extent considered necessary by the machineman, the mixture of stuff and water runs on to the wire. As soon as the wire is moving, and the water begins to drain through it and fills up the low level box by way of save-all trays and chutes, the fresh water may be partly shut off. Sufficient overflow is left for a few minutes to compensate for any change the machineman may have to make. As soon as the machineman has got the correct proportion of stuff and water, the water valve may be closed so as to leave only a very small overflow from the high level box. Meanwhile, the back-water is being pumped back to the white-water distributing head tank, and is immediately finding its way to the mixing box. As soon as the machineman has enough white-water available, he turns it on, and at the same time

turns off the fresh water, so that in a very short time he is using only white-water, and all fresh water ceases to be used.

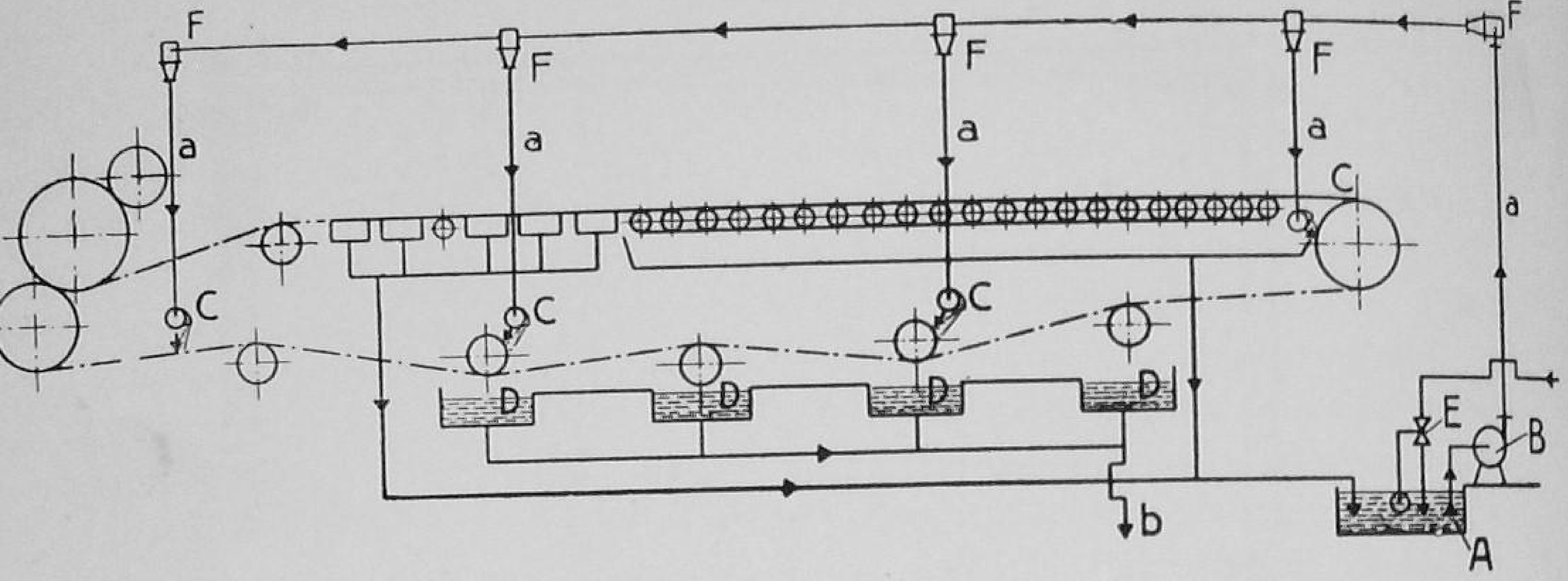


Fig. 81.—The Rotor White-water Circulation System

The white-water from the save-all tray and the back-water from the suction boxes are both collected in pit 'A'. By means of pump 'B' this water is conducted through the supply pipes 'a' to the Rotors 'C', and is used as spray water. The trays 'D' collect this white-water again and conduct it through the supply pipes 'b' to the existing pump for diluting the stuff in the mixing box. Fresh water, which is necessary during the starting of the machine, is automatically added by the floating valve 'E'. 'F' is the turbine which causes the water to spin.

The back-water will gradually attain to its full saturation of size, loading, colour, etc., and the stuff coming from the chest will get all the benefit of these things returned over and over again. It is an advantage to have a connexion from the suction pump which deals with the suction boxes. The fine fibres, loadings, starch, colour, etc., may then be led back to the collecting tank, and any overflow pumped to a tank in the beater room to be used in furnishing and emptying the beaters. Some fine mills, however, prefer to lose the suction box water rather than risk having in the paper any dirt and lumps of fibre from the suction box packing.

The Rotor White-water System and Spray Nozzles (Figs. 81 and 82).—The easiest way to solve the white-water problem is, of course, to have as little white-water as possible. It is well known that every drop of fresh water brought into the system on the paper-machine becomes white-water when leaving the machine, and usually carries away fibres, fillers, chemicals, size, etc. Almost all the fresh water on the paper-machine itself enters the system through spray pipes, and it is astonishing what a great quantity of fresh water is admitted by one spray pipe. The quantities of water passing this way into the white-water system are much higher than would be expected, and the table gives the quantities of water for various sizes of orifice and different pressures.

In many mills the fresh water spray pipes about the wet end of the

machine have simply been copper or brass pipes drilled with a number of round holes. These are very expensive in water, and do not usually achieve

[Reiss Engineering Co. Ltd.

FIG. 82.—SPECIAL BENDS AND PIPES OF ROTOR WHITE-WATER CIRCULATION SYSTEM, TO CAUSE THE WATER TO SPIN THROUGH THE PIPES SPIRALLY, AND THUS KEEP THE DISCHARGE OPENING CLEAR

the desired object of washing every part of the wire, dandy roll or wire return roll, because of the gaps between the orifices in the pipe. What is really wanted is a continuous curtain of water covering every part of the roll, wire or dandy which is to be sprayed.

Excellent spray pipes, giving this flat curtain of water, have been available in America for many years, but until recently it seems to have been impossible to obtain them in England.

The first early design to achieve this object of a flat curtain consisted of the use of cylindrical nozzles which sprayed against deflector plates, thus forming the flat jet. These, however, had the objection that they caused a lot of splashing, and reduced very much the pressure which it was important to apply on to the wire in order to clean it. Now it is possible to obtain special spray discs which give a flat, triangular, fan-shaped spray, and can be arranged at larger pitches than the ordinary orifice holes. By employing these special spray discs, far fewer nozzles are necessary, and much smaller quantities of water, with a very much more efficient spraying of the dandy or wire. It is claimed that water savings up to 80 per cent, compared with the old-fashioned spray pipe, have been achieved in very many cases. By reducing the fresh water quantity at the wet end of the machine from 100 per cent down to as low as 20 per cent or 30 per cent of the original quantity, the

back-water is reduced in a similar proportion, and any existing recovery plant can work with a higher efficiency if the through-put per hour is reduced. Further than this, there is a tremendous saving in clean, fresh water.

These new spray pipes with the special orifices are incorporated in the latest design of Rotor White-water System supplied by the Reiss Engineering Company. It is further claimed that, by adopting this system, the use of fresh water on the wet end of the machine for sprays and other purposes can be entirely eliminated, even on machines making fine, high-class papers. To achieve this object, however, it is very important that the returned water, or white-water, shall be given no opportunity to form deposits. This requires the shortest possible circuit between the place where the return water forms and the spray pipe where it is to be used. Also the velocity in the pipes should never fall below a minimum, which is about 9 feet per second, and may be up to as much as 12 feet per second.

It may be pointed out that every drop of white-water intended for spraying purposes has previously passed through the wire, and therefore the size of particles contained in the white-water is smaller than the wire mesh through which it has passed. Provided, therefore, that no opportunity has been given for conglomeration of fibres, loadings, etc., it should be easy for the returned water to pass through the comparatively large orifices of spray discs, and then pass once more through the wire meshes, strainer slots, etc. Where wires are to be cleaned, however, it will not always be found satisfactory to use returned water, especially on very fine wires. The reason for this is that these wires become easily clogged up with fine fibres, and unless absolutely clean fresh water is used to wash them, on the return run, they will never drain so well, and the appearance of the sheet is seriously interfered with.

The spray discs on these new spray pipes are flat and circular, and made of a hard and corrosion-resisting material. Normally the orifice bores are between $\frac{3}{32}$ inch and $\frac{1}{8}$ inch; the discs are sharp-edged, with a flat groove inside, and a deep groove outside, the grooves, being arranged under an angle of 90 degrees, not allowing formation of deposits or choking of orifices.

If steam has to be used to heat the stuff for heavy or wet beaten papers, the high-level water box is where it will give the most economical and efficient results. The pipes of the water system, and indeed all pipes conveying back-water and stuff, must be copper with brass or copper bolts and nuts throughout. The back-water pipes should be taken apart and thoroughly

scoured out frequently. A tight bundle of strips of old machine wire pulled through by a good strong rope makes a very efficient scrubber.

The water system of a machine should never be allowed to get dry. If this happens during a shut down, or over the week-end, a quantity of scale or slime is sure to break away when the water is put on, and may continue to come through and get into the paper for hours. The pipes should be left full, with a trickle coming through the water gate and a little overflowing. It will be found, in many mills, that the pipes are allowed to go uncleaned for months, in order to save the few hours this takes, or the few shillings paid for overtime to the fitters who take down and replace the pipes. This is the worst possible mistake, for a machine cannot produce clean paper if the water system is neglected.

From now onwards we must deal with the stuff and water mixed in paper-making proportion after it leaves the stuff tap, which may be from $\frac{1}{2}$ to 2 parts of stuff to 100 parts of water.

The Sand Traps.—These are the wooden chutes through which the stuff and water flow, leaving in their passage heavy foreign matter, such as sand, specks of metal, etc., and any substances heavier than fibre.

A difference of opinion exists as to whether deep, narrow chutes, or wide, shallow chutes are most efficient. It is contended by some that deep, slow-moving stuff gives the best chance for, say, a piece of metal to fall to the bottom. Others say that the stream must be shallow and ripply to break up the clusters of fibres and allow the piece of metal to drop. The truth may be with both views, but there seems to be no reason why chutes should not be made with a deep channel in one part and wide and shallow in the other. There ought to be several depressions in the bottom of the chutes at intervals, about 3 or 4 inches deep, in which dirt, metal, etc., may be trapped, otherwise it will gradually travel to the end of the chutes and get into the strainers.

It is a very good plan to have the bottoms covered with strips of old wet felt with a good nap and of a handy length to facilitate washing. These are held down by strips or bars of lead. Two sets of strips should be available, of which one set is kept clean and ready to replace the other. This will save a few minutes' time when washing out. The 'hairy' surface of the felt is very effective in holding back sand and all solid particles. Sometimes 'ladders' are laid in the bottoms of chutes. They are not much good and generally become sources of dirt through neglect. Some mills, making fine papers, have installed electro-magnets in their sand traps.

These magnets attract and retain all particles of iron, and even rust, so effectively that the rusty specks and spots so often seen in tub-sized papers

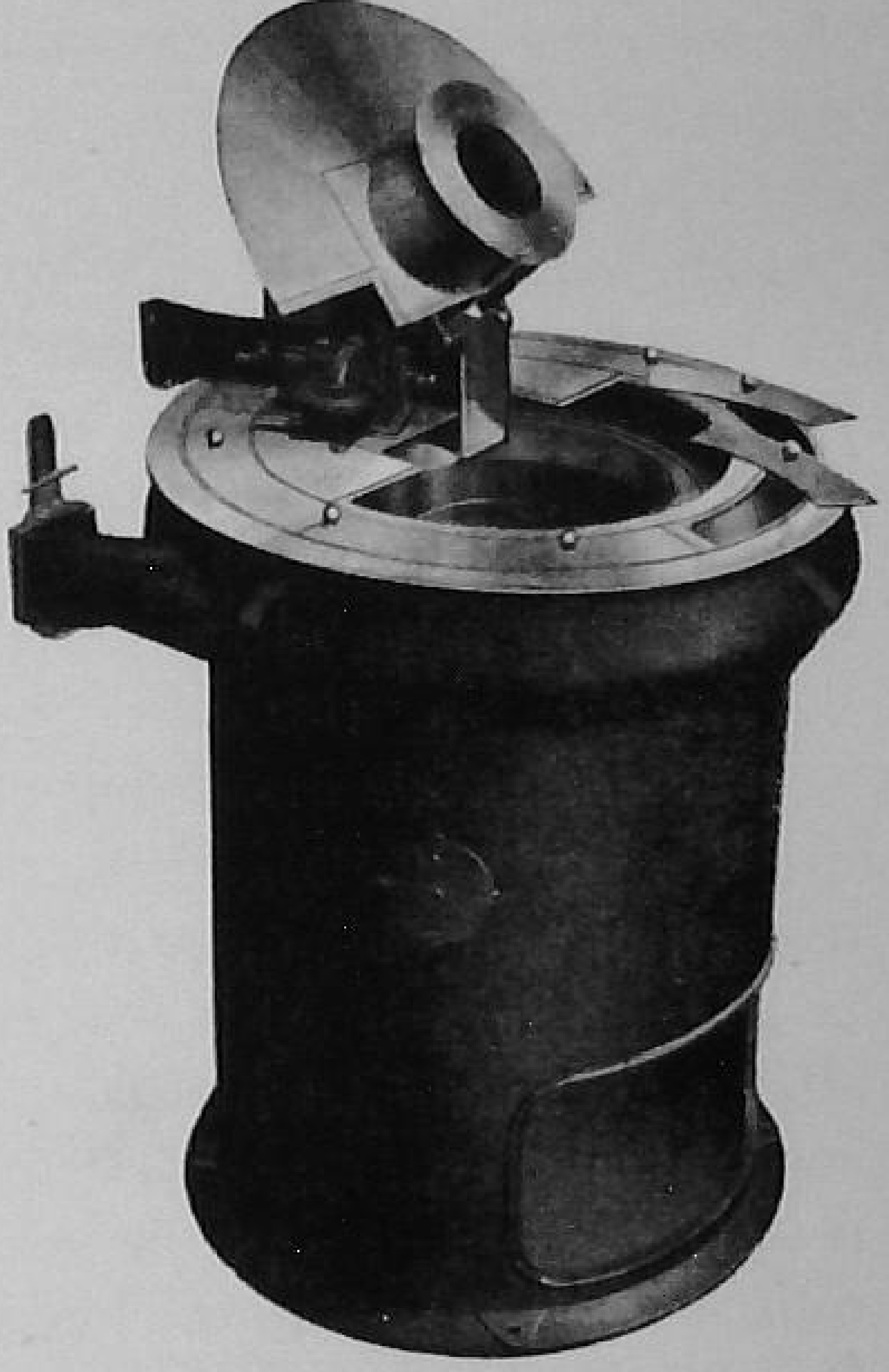
are entirely eliminated. Strangely enough, specks of all kinds of metal seem to be attracted and stick about the poles of the magnet. A good substitute for this machine can be made by magnetizing a number of old files and arranging them on the bottom of the chutes. Though not by any means so powerful as the electro-magnet, these magnetized files help to do their bit in giving clean paper.

The sand traps may be utilized to catch a little of the paper-maker's worst enemy—rubber. A board or boards fixed with their under edges just below the level of the stuff, across the chutes, retain a great deal of scum or froth in which may be found specks of rubber that have floated to the surface. If these boards are inclined at an angle away from the flow of the stuff, floating particles of all kinds will be washed up and stranded on their sloping surfaces.

It is generally agreed that the longer the chutes the more chance has the stuff to get rid of dirt, but there is a limit which must be set for economical reasons. Where very frequent changes of sorts are necessary, long chutes may be wasteful both in stuff and time, since every alteration of stuff or water alters the level of the stuff flow, and may even cause the dirt to be disturbed and begin to come through with the stuff. When this happens, the only cure is to shut and wash out the sand traps. The best plan for the machine is to have about 50 yards of chutes, with a by-pass at 25 yards, and a short cut for very thick or wet beaten papers. Banks and all thin papers may be run with the full length, as they have proportionately a heavy flow of water with the stuff. Medium weights and small orders may be run the 25 yards, and those papers which must be run with very little water take the shortest way. If it is attempted to run the latter class through too long chutes, the flow will be sluggish, and most probably will follow a narrow channel in the centre, leaving thick stuff stagnant at the sides. In connexion with this, it may be mentioned that when the machineman opens the water gate to run more water with the stuff, the weight of the sheet increases for a few minutes, owing to the slight flooding effect driving the stuff in front of it. Conversely, if he shuts off water, the weight falls temporarily, owing to the checking of the flow. It is, therefore, important that the machineman should keep accurate note of the time he makes the change and be prepared for the results, which, unless understood, may mislead him into altering his stuff gate. The best method for keeping in touch with the weight is to follow the change by altering the driving speed.

At one time it was considered necessary to have an elaborate 'mixing box' where the stuff and water emerge from their respective gates. This opinion still persists, but many machines have none, and never experience

any difficulty from their absence. The best mixing may be obtained by causing the water to strike the flow of stuff as it leaves the stuff gate at right angles on an inclined plane, or the water may be made to fall on it from above. The force of the water effectually breaks clumps of fibres and carries them well mixed into the chutes.



[*Blackfriars Engineering Co. Ltd.*

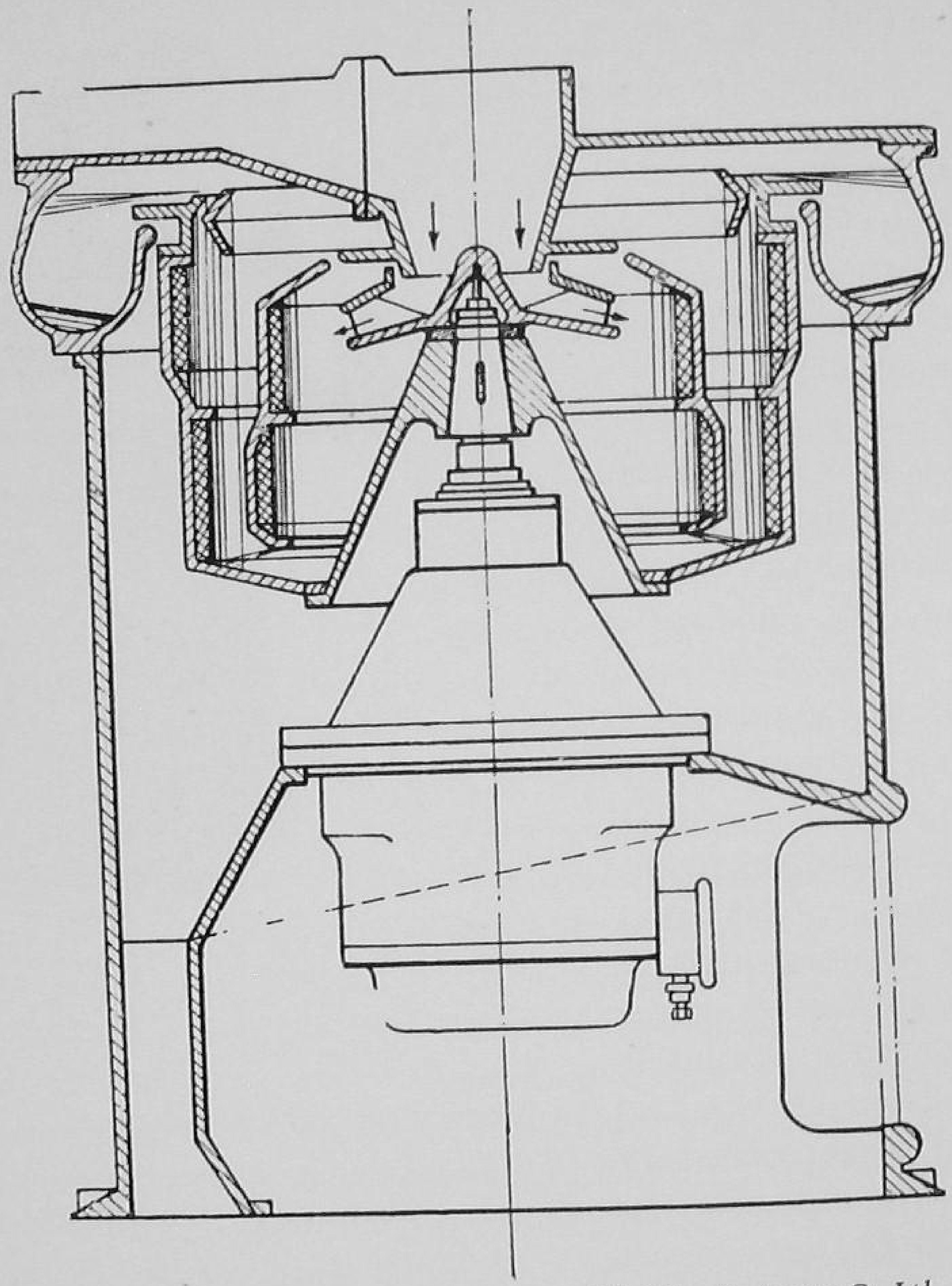
FIG. 83.—THE ERKENSATOR, SIZE IV, SHOWING LID OPENED FOR CLEANING, AND REVEALING THE INNER CYLINDERS OR BASKETS

CENTRIFUGAL CLEANING MACHINES

Most mills nowadays which make fine papers rely almost entirely for the cleaning of their stock and the freeing of it from foreign matter such as metal, sand, shive, rubber, etc., on centrifuges, such as the Erkensator, which was the first of these machines. They depend for their efficiency on the action of centrifugal force. The fact that cellulose, water, and to a less extent loadings in general, have specific gravities sufficiently near to each other, enables these to pass through the machine together, while heavier and lighter substances are retained behind projecting rings, or in the case of lighter particles are removed by skimmers.

The machine (Figs. 83 and 84) consists of the following parts: an outer container with lids for access, and a trough running right round the top for receiving the clean stock. Inside, a series of phosphor-bronze cylinders or rings, which fit one inside the other, are driven by a motor from underneath. The stuff is led into the centre of the machine and pours down to the bottom of the inner container. The whole of the inner vessel is revolving at a very high speed, so that the stuff when it reaches the bottom is immediately flung out in all directions against the inner wall of the innermost cylinder. The spinning action causes the stuff to drop to the bottom of the ring, where it meets with the opposition of a lip or ring, over which it has to pass. Behind this first lip the heaviest particles are trapped, because their specific gravity is so great that they are unable to overcome the action of the centrifugal force, and climb inwards over the lip. The water and lighter cellulose fibres pass this lip, and are immediately flung out further into

another ring, up which they travel on account of the pressure behind them, until they meet another projecting lip half-way up the second ring. Here,



[*Blackfriars Engineering Co. Ltd.*

FIG. 84.—SECTION OF ERKENSATOR, SIZE IV, SHOWING THE PATH OF THE STUFF AS IT PASSES THROUGH
The shaded portion represents the 'foreign matter' trapped behind the collection rings.

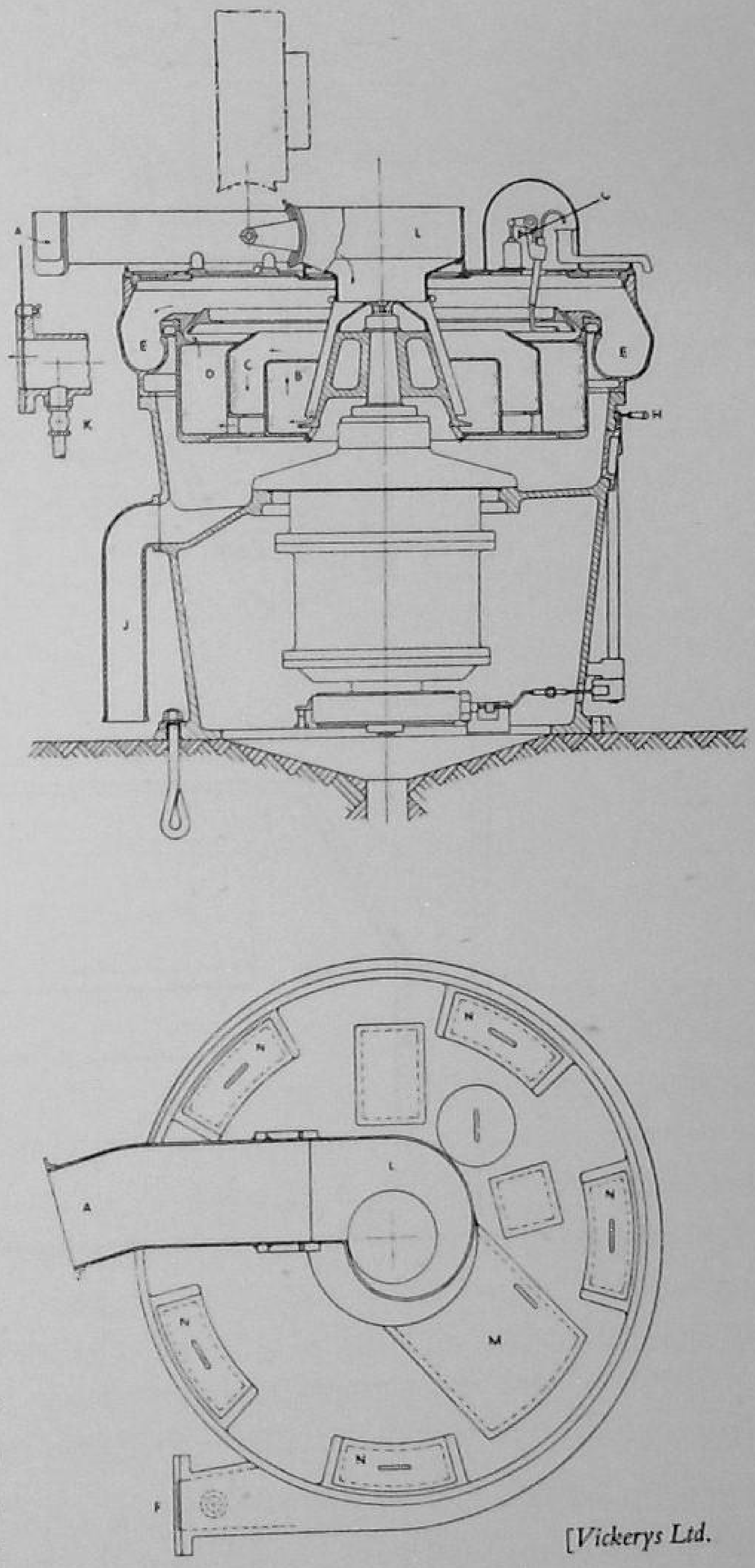
other impurities, less heavy than those retained at the first lip, are trapped, and the fibres and water, passing over the lip, are flung out still further into a third ring of still greater diameter. They proceed to climb up the inner wall of the third ring, where they meet yet another projecting lip, and it is in this ring that most of the shive is caught. By the time the fibres and water have reached the end of this third ring they are practically entirelly free from all foreign matter which is of a higher specific gravity than cellulose.

At this point it is possible to remove lighter things, such as rubber, cork,

etc. This is done by causing the nozzle of the skimmer to plough the inner surface of the water and fibre just as it is passing out of the final ring on its way to the collecting trough of the machine. This top skimming contains, of course, valuable fibre, and it is at once led into an auxiliary strainer, where the impurities are separated out of the stock, which then goes back to the mixing-box chest or back-water supply service.

It is often argued that these centrifugal machines are wasteful of stuff, but when it is remembered that these machines need to be cleaned out, say, only once every 12 hours, and in many cases at much less frequent periods, it will be seen that the loss is negligible, and that the greatest portion of the loss consists, in any case, of impurities.

Against this loss also must be considered the fact that the paper can be guaranteed to be absolutely clean and free from specks, and that it is also no longer necessary in, for instance, the case of a rag mill to employ any sorters to sort the rags in search of buttons, metal fasteners, pins, etc. The rags, in fact, unless they have to be sorted to remove certain qualities, can be passed straight from the bale into the chopping machine, and all the subsequent removal of impurities may safely be left to the Erkensator.



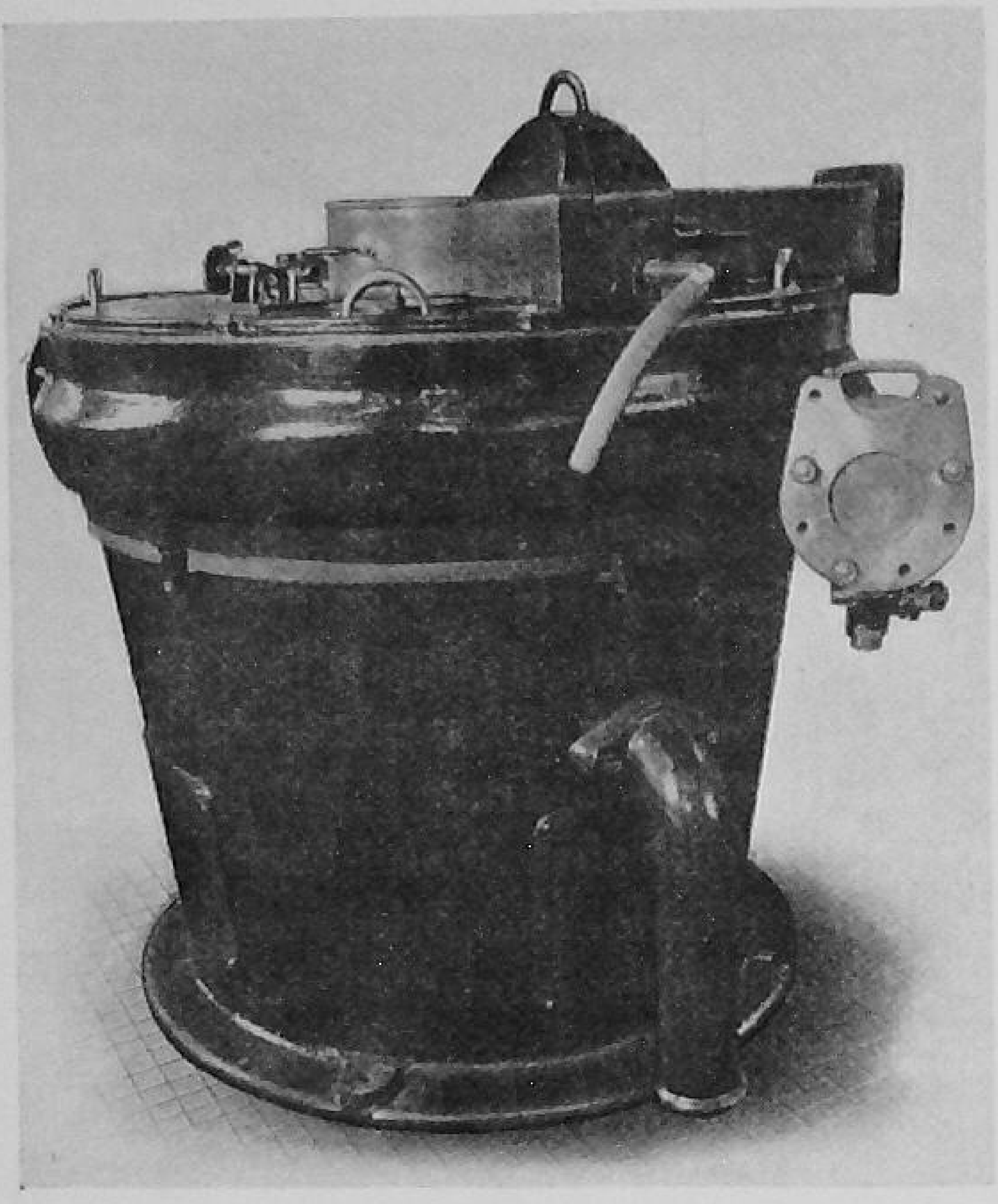
[*Vickerys Ltd.*

Fig. 85.—Vertical Elevation and Plan of the Purifuge Centrifugal Stock Cleaning Machine

This machine has three external cylinders, and is very accessible for cleaning.

To get the best results from these machines, it is necessary that stock passing through them should be very dilute; in the case of wood pulp,

densities should not be greater than 0·75 per cent, and for rag stuff about 0·5 per cent or less. At these consistencies the machine will remove practically the whole of the shive, which has very little greater specific gravity than the cellulose itself.



[*Vickerys Ltd.*

FIG. 86.—THE PURIFUGE CENTRIFUGAL STOCK CLEANER

Another centrifugal machine is the Purifuge (Figs. 85 and 86), which works on more or less the same lines as the Erkensator, but it has the advantage that it is made in England by Messrs. Vickerys.

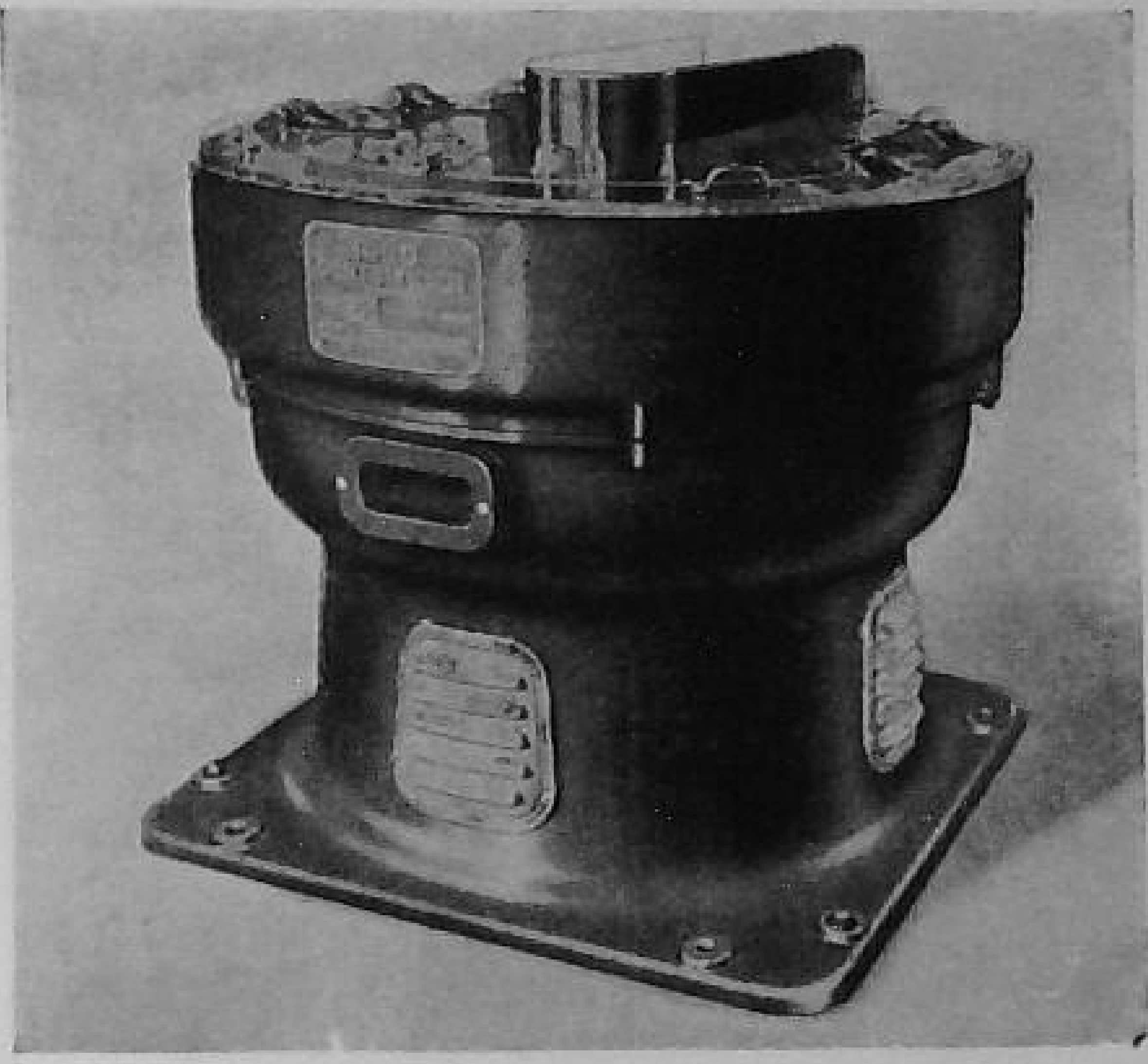
The Bird Centrifiner, which is made by the Bird Machine Company (Fig. 87), is of similar design to the aforementioned centrifugal stock cleaning machines, and has a high capacity.

It is sometimes said that the centrifugal machine removes immediately the heavy loading material, and it must be admitted that it does this immediately it is started up, in order to fill the 'bolster', as the lining inside the rings is called. This only takes a few moments, and after that no more loading is, in fact, removed. In order to get over this difficulty, it used to be common practice to put in a bucketful of loading before the stock was turned on; now, however, it has been found to be much more satisfactory, from every point of view, to add the loading in a continuous stream after the stuff has passed through the centrifugal machine. The section of the latest type of Erkensator and the path of the stuff can be easily traced through the machine (Fig. 84).

The maintenance costs of these machines are extremely low; there is nothing to go wrong with them, except, perhaps, a bearing, and there are many of these machines running continuously which have been in operation for 20 years without having broken down, and with no expense for repairs.

Messrs. Thomas Broadbent, of Huddersfield, have also made excellent centrifugal cleaning machines suitable for paper stock. Many of these have been made in stainless steel. A complete installation of these is shown in Fig. 88, showing three centrifuges and collector box.

The Vortrap (Fig. 89) has been produced with the idea of separating dirt and other impurities from the stock without employing the power and apparatus required in other centrifugal machines. The principle of it depends on centrifugal action. As will be seen in the accompanying drawing, it comprises a vertical cylinder of small diameter divided into sections by perforated partitions. The stuff is injected into the cylinder tangentially, causing it to spin round rather like a vortex. This action throws the heavy particles to the outside of the cylinder, and they rise up to the top where they meet the upper partition. Here they are deflected downwards through the centre hole of the partition, only clean stock passing upwards along the axis of the cylinder to the trumpet-shaped outlet. The dirt which has passed down the centre falls into the funnel at the bottom and thence into the waste receiver. This waste receiver can be shut off and emptied while the vortrap is still in operation.



[*Bird Machine Co., South Walpole, Mass.*

FIG. 87.—BIRD CENTRIFINER

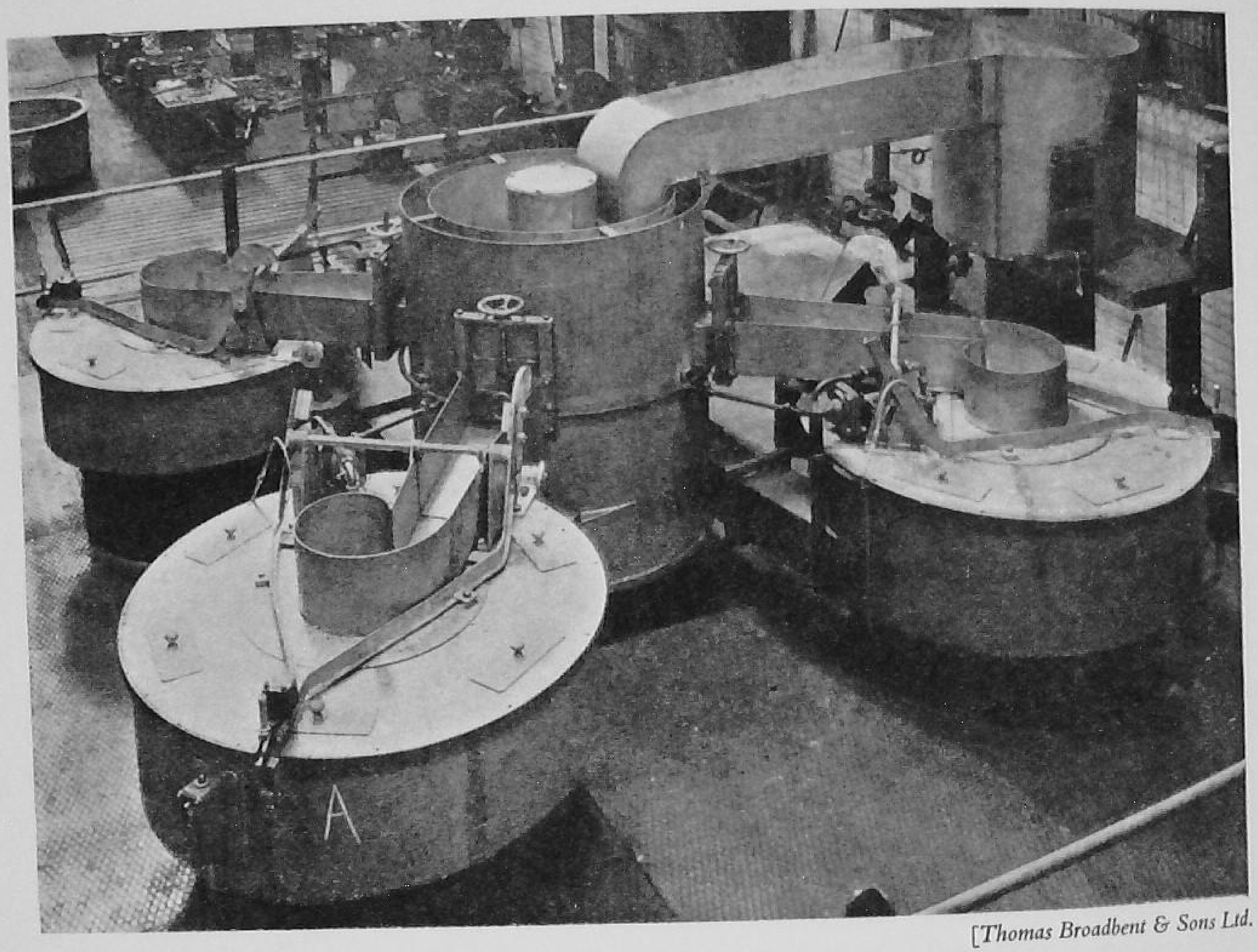
A centrifugal stock cleaning machine, working on the same principle as the other centrifugal machines.

It is claimed for this apparatus that it is very low in first cost compared with other centrifugal machines, and that it separates a large quantity of the dirt usually contained in paper stock. The Vortrap is fully described in Chapter XIV.

The Dirtec (Figs. 91 and 92) is a static type separator for the removal of dirt from pulp and paper stock. The machine has no moving parts, the separation being obtained by the employment of the differences in pressure of the stock itself. It is effective and suitable for all types of stock, both heavy and light dirt being removed continuously without stopping for cleaning.

It is, however, still necessary to keep the strainer in use. Froth is produced in great quantities by the excessive aeration in the centrifugal machines. Coagulation takes place when the stuff has a long distance to travel to the breast box, and creates difficulties in the formation of the sheet on the wire. Knots, small clumps of unseparated fibres and shives, such as are found in esparto and wood pulp papers, and which are of the same specific gravity as cellulose fibres, are still to be dealt with. It is therefore inadvisable to run a strainer with a more open cut than is required for getting the stuff freely through, though in some cases the cut may be much more open.

The earlier forms of strainers were flat boxes with perforated metal plates forming the bottom, the perforations being in the form of narrow slits about

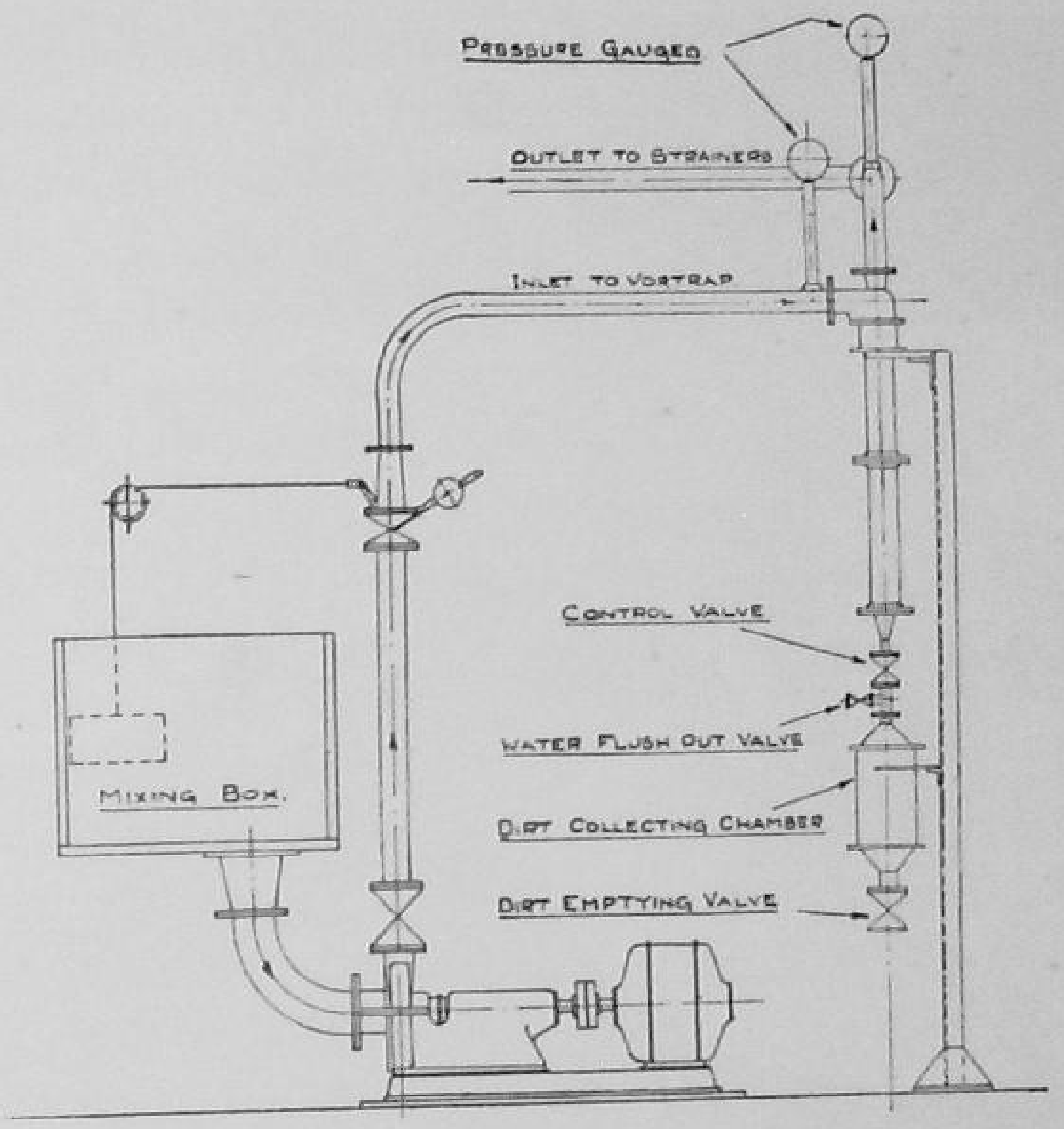


[*Thomas Broadbent & Sons Ltd.*

FIG. 88.—BATTERY OF BROADBENT CENTRIFUGAL STOCK CLEANING MACHINES IN STAINLESS STEEL, COMPLETE WITH DISTRIBUTING AND COLLECTOR BOXES

2 to 3 inches long. The slits vary in width according to the form of pulp which has to be strained, and the 'cuts', as they are called, are known by numbers, such as '3' cut, or by their width in thousandths of an inch (see page 198). The cuts are spaced about $\frac{1}{4}$ inch apart, or far enough to prevent long fibres from getting their ends through two different slits. Flat strainers of a modified and improved type are used extensively in America for straining all kinds of stock, and they still have adherents in this country, especially among paper-makers dealing with strong rag stock. These strainers consist of a flat trough, the bottom of which is formed of the strainer plates with slits. Underneath is another trough, the bottom consisting of a flexible metal diaphragm, attached underneath to rods which in turn are in contact with cams on a rapidly revolving shaft. These cams lift and drop the rods, and this causes the metal diaphragms to oscillate up and down, thus causing

an alternate sucking action through the strainer plates, causing a partial vacuum on the downward stroke and a reflex action on the upward stroke.



[*Walmsleys (Bury) Ltd.*

FIG. 89.—THE VORTRAP, SHOWING THE COMPLETE ARRANGEMENT AND PATH TAKEN BY THE STUFF

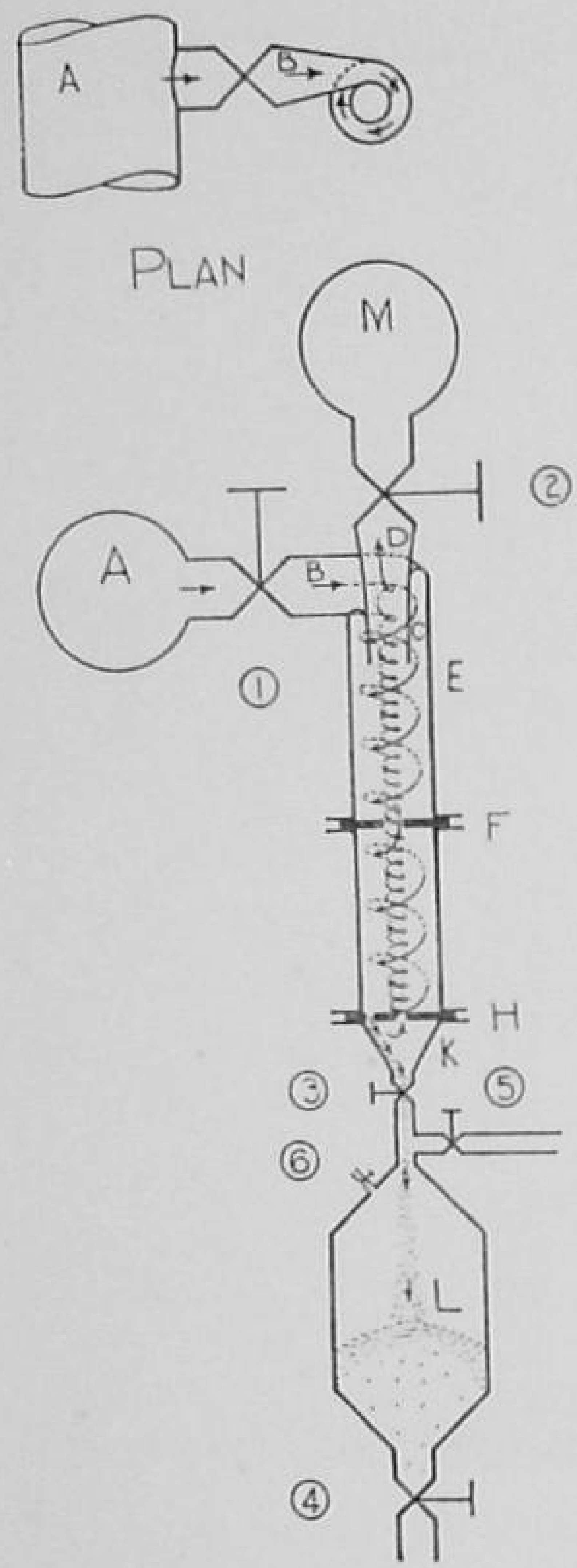
The suction downwards draws fibres and water through the slits, but it also causes fibres to be drawn over the narrow slits and so clogs them up. The 'reflex' or upward flow on the upward stroke of the diaphragm pushes them away, mixes them up with water and some are thus ready to flow through the slits at the next downward movement of the diaphragm.

If there were no 'reflex action', the strainer would quickly become completely clogged up with a coating of stuff, just as in the case of the revolving drum or mould on a 'mould' machine. This reflex action is an essential feature of all strainers, and many different methods are used to promote it.

The slits are always narrowest at the side on which the fibres enter, and they open out towards the opposite side. This prevents them becoming clogged up by accumulations of fibres trying to squeeze through.

The passage of the fibres and water through the slits is brought about by two chief causes: first, gravity, or the weight of the water in which the fibres are suspended; secondly, the sucking action of the diaphragm.

The older type of jog strainers are operated by ratchet wheels, the teeth of which engage and lift rods fixed to arms projecting from the sides of the vat. The opposite side of the vat is hinged, so that the vat moves freely up and down. The action is, therefore, actually a tipping motion. These strainers are still much in evidence, as they are to be found in most mills, being used in conjunction with the more recent revolving strainers as 'back knotters' or auxiliary strainers, to which we shall refer in greater detail later on.



[*Walmsleys (Bury) Ltd.*

FIG. 89A.—DIAGRAM OF VORTRAP, SHOWING DETAILS OF OPERATION AND PATH OF STOCK AND REJECTED JUNK

The greatest drawback to the use of these flat strainers is that they are constantly becoming filled up with the coarse stuff, shive, rubber, dirt, etc., which they have prevented from getting through and into the paper.

In order that the strainer will still continue to pass sufficient stuff to keep the weight right at the machine, it is necessary that it should be frequently cleaned and rubbed over by the machineman. This is very unsatisfactory, and it leads to lots of dirt, etc., being let through; it also takes time and interferes with the weight. Various devices have been resorted to in order to make this cleaning automatic and continuous, but none of them is really adequate.

In some forms a trough is provided at the opposite end to that at which the stuff flows on, and in this the coarser and uncleaned stuff collects, along with rubber, and is led away.

There is no doubt that one of the chief necessities which caused the invention of the revolving strainer was the need for automatic cleaning of the plates. In the revolving strainer the plates form the circumference of a skeleton cylinder, which revolves partly submerged in a semicircular cast-iron trough, and is called the drum.

There are two types, the inward and outward flow, and in both the slits or cuts are kept clean with a strong shower of water applied by means of a perforated pipe.

In the case of the 'inward flow' the stuff is led into the trough, and has to pass through the slits into the inside of the drum, and the cuts are cleaned by a shower pipe inside, which forces water upwards through the drum either at the top or at the sides, well away from the stuff in the vat. Some of this

water and the fibres which it dislodges are caught in a trough and led away to the auxiliary strainer. The remainder of the water which is not caught

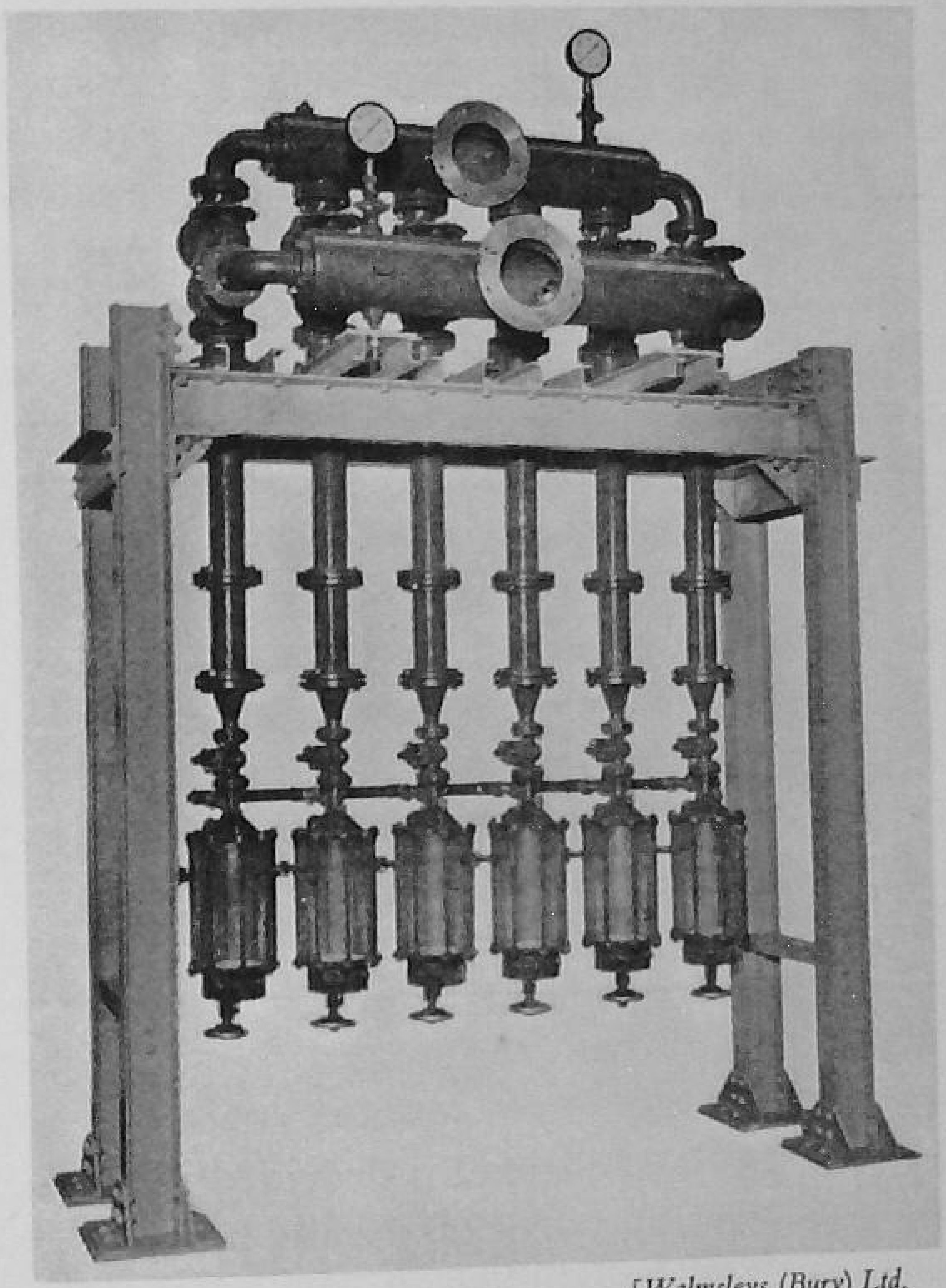


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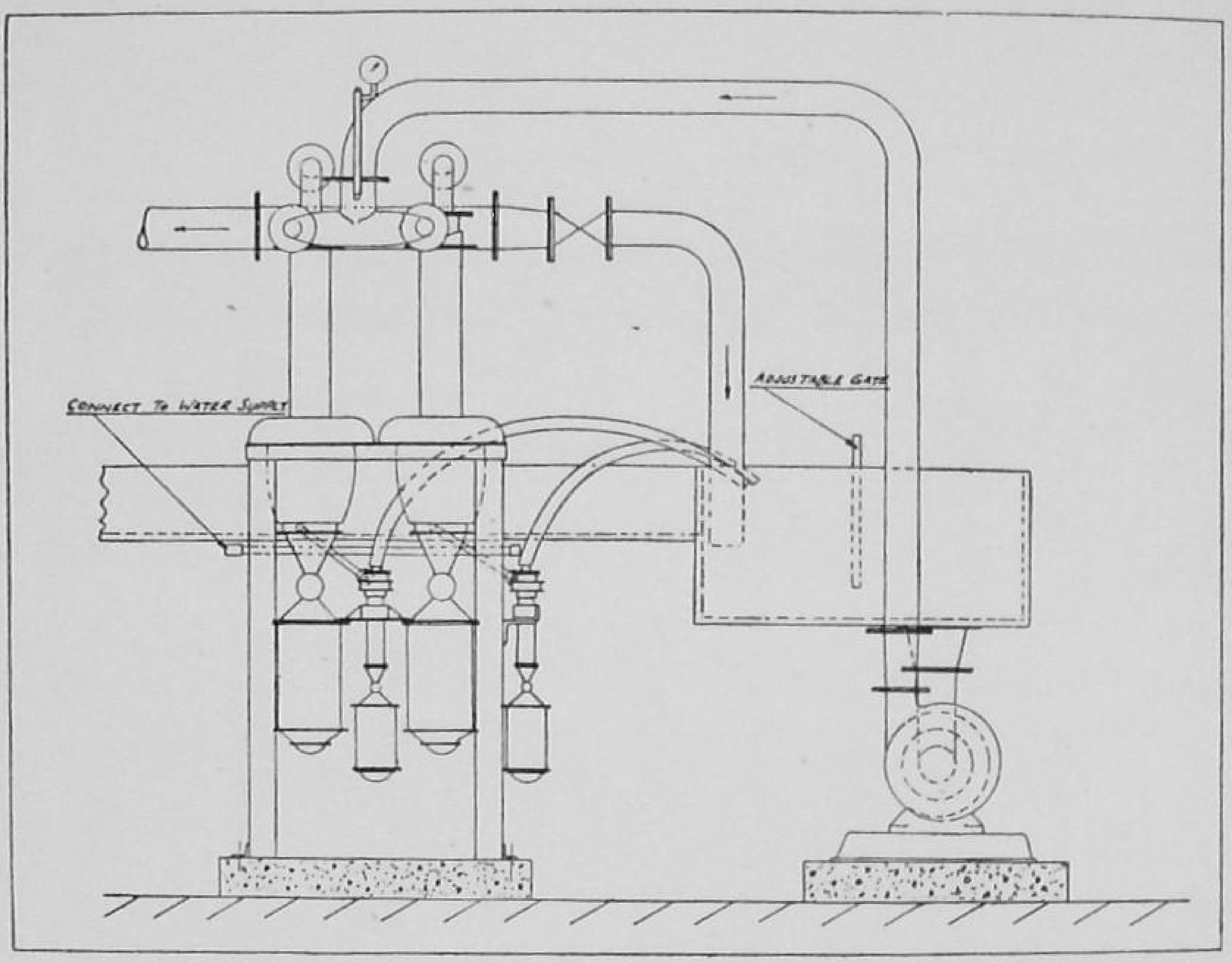
FIG. 90.—BATTERY OF SIX VORTRAPS

and the hanks and knots of fibres fall back into the vat, and those knots which are not broken up sink to the bottom of the vat, and either lie there until cleaned out or pass away with the dirt, etc., to the auxiliary strainer through a tap at the lowest point of the trough.

In the 'outward-flow' (Fig. 93) strainer the shower is applied from above and outside the drum, and the dirt, knots, etc., fall back into a metal trough placed horizontally along the inside of the drum, and are washed away to the auxiliary strainer.

The inward-flow strainer is superior to the outward-flow, especially for better-class papers, where freedom from dirt and blemishes of all kinds is of the first importance. It is much more easily cleaned, because most of the objectionable stuff never gets into it, but remains outside in the trough.

When the stuff flows in from the sand tables, any heavy dirt, grit or knots will naturally sink to the bottom, or if they come in low down they will be



[*Vickerys Ltd.*

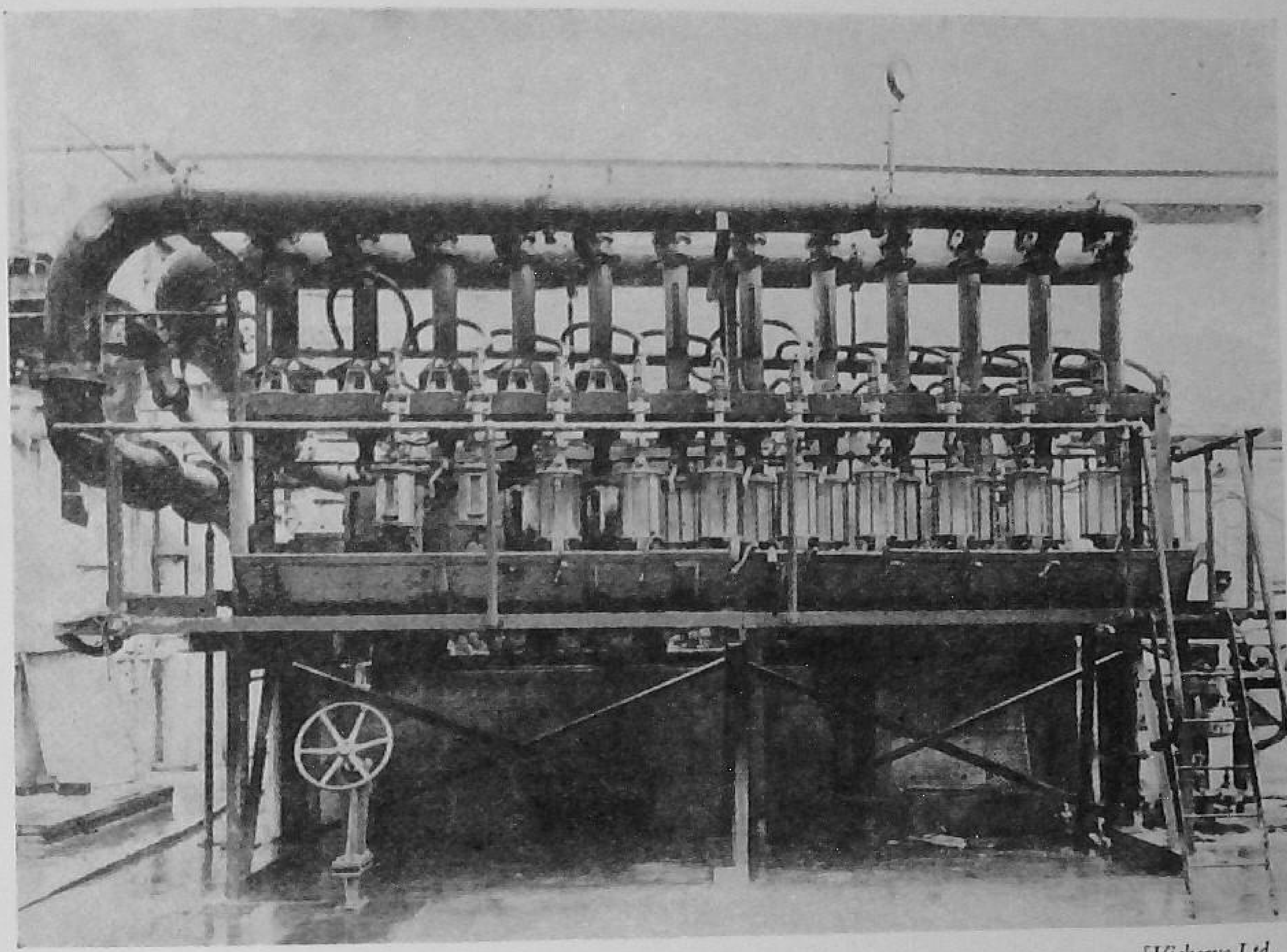
FIG. 91.—DIAGRAMMATIC ARRANGEMENT OF A TWO-UNIT DIRTEC INSTALLATION

inclined to stay down. A deep channel is provided in the bottom of the vat in which these things collect, and a cock is usually provided, which can always be kept partly open to allow them to be carried away to the auxiliary strainer.

Further, in some strainers an adjustable sluice is provided at about the normal level of the stuff in the vat, and this can be so raised or lowered as to allow the top scum, in which most of the rubber floats, to run off into the auxiliary strainer. Thus two means are provided for getting rid of some of the various causes of blemishes in the paper.

The principle of working of most of the inward-flow strainers is much the same. The water in which the fibres are suspended flows through the slits to the lower level inside, carrying fibres with it, but in order to prevent a film of waterleaf being formed on the outside of the drum, the reflex action already referred to has to be set up. This is done in one type of strainer by vibrating the flexible drum itself, and so causing waves and ripples to ebb and flow through the slits. More fibres and water will pass through than will be passed back again, owing to gravity and the flow of water to its own level. In the Banning and Seybold type of inward-flow strainers the reflex action

is caused by the oscillating of flappers, or large perforated plates fixed to a strong shaft. This shaft is placed immediately under the lowest part of the



[Vickerys Ltd.

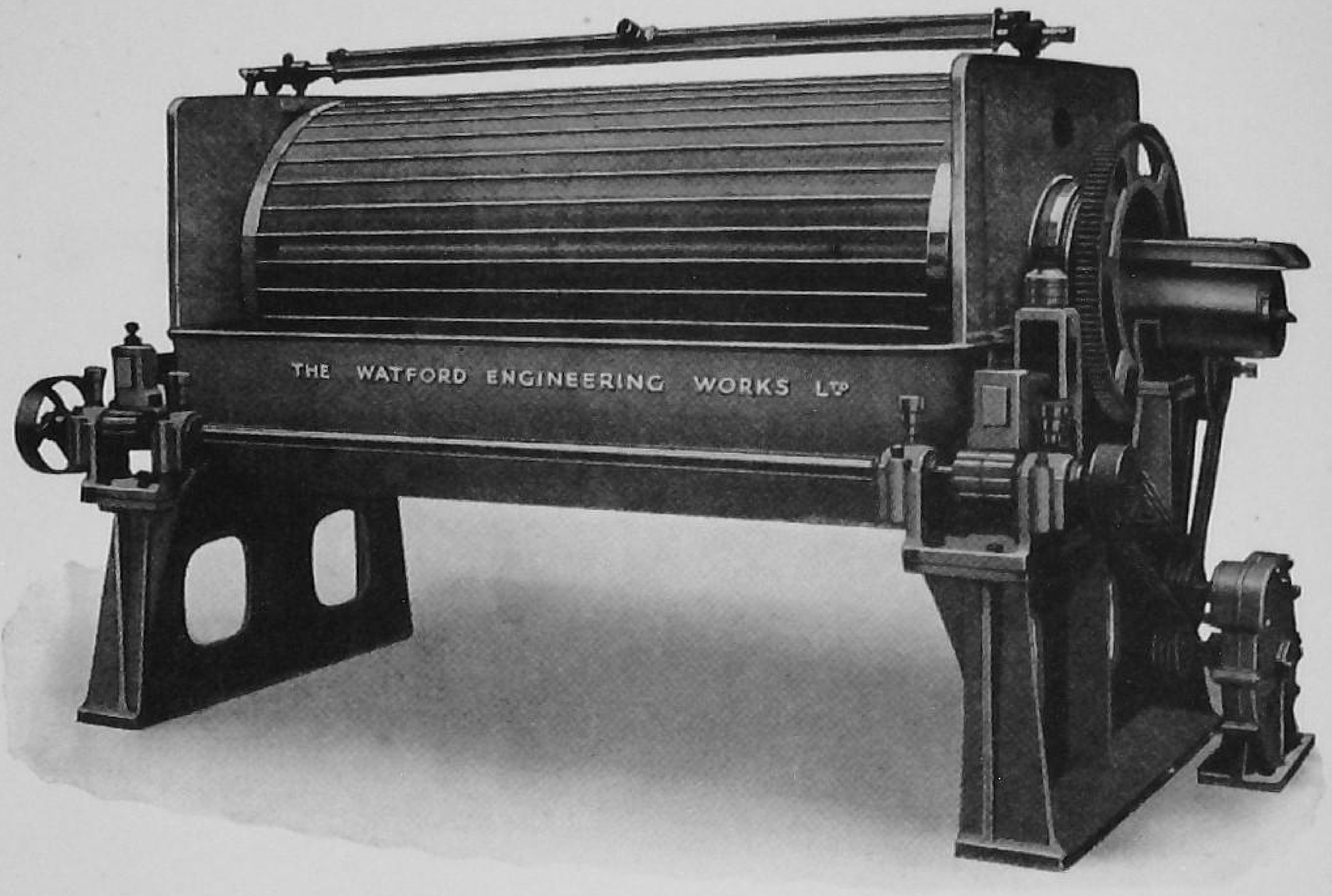
FIG. 92.—LARGE INSTALLATION OF VICKERY DIRTEC STOCK CLEANING EQUIPMENT

revolving drum, and it moves backwards and forwards, causing the plates to flap like wings in the stuff and send it in waves up against the slits of the drum.

The motion is very effective in passing the stuff through, but the mechanical action is very drastic and, being also erratic, it entails the use of very heavy shafting and strong metal plates, which consume a large amount of power and lubricating oil and cause a good deal of wear.

Another excellent type of inward-flow revolving strainer is that made by James Bertram & Sons, and known as the Leith Walk Full-Drum Strainer (Fig. 94). This is the simplest inward-flow strainer we have seen, and it has many advantages to recommend it. It is noiseless, simple in construction, easily maintained and efficient in working. It consists of the usual cast-iron vat lined with glazed tiles, and the drum may be either driven by a ratchet mechanism, to give an intermittent motion, or it may revolve slowly and continuously.

The method used to produce the reflex action to induce the passage of the stuff, is much the same as that used in the later models of the flat strainer;



[*Watford Engineering Works Ltd.*

FIG. 93.—THE WATFORD IMPROVED 'WANDEL' STRAINER, OUTWARD-FLOW TYPE

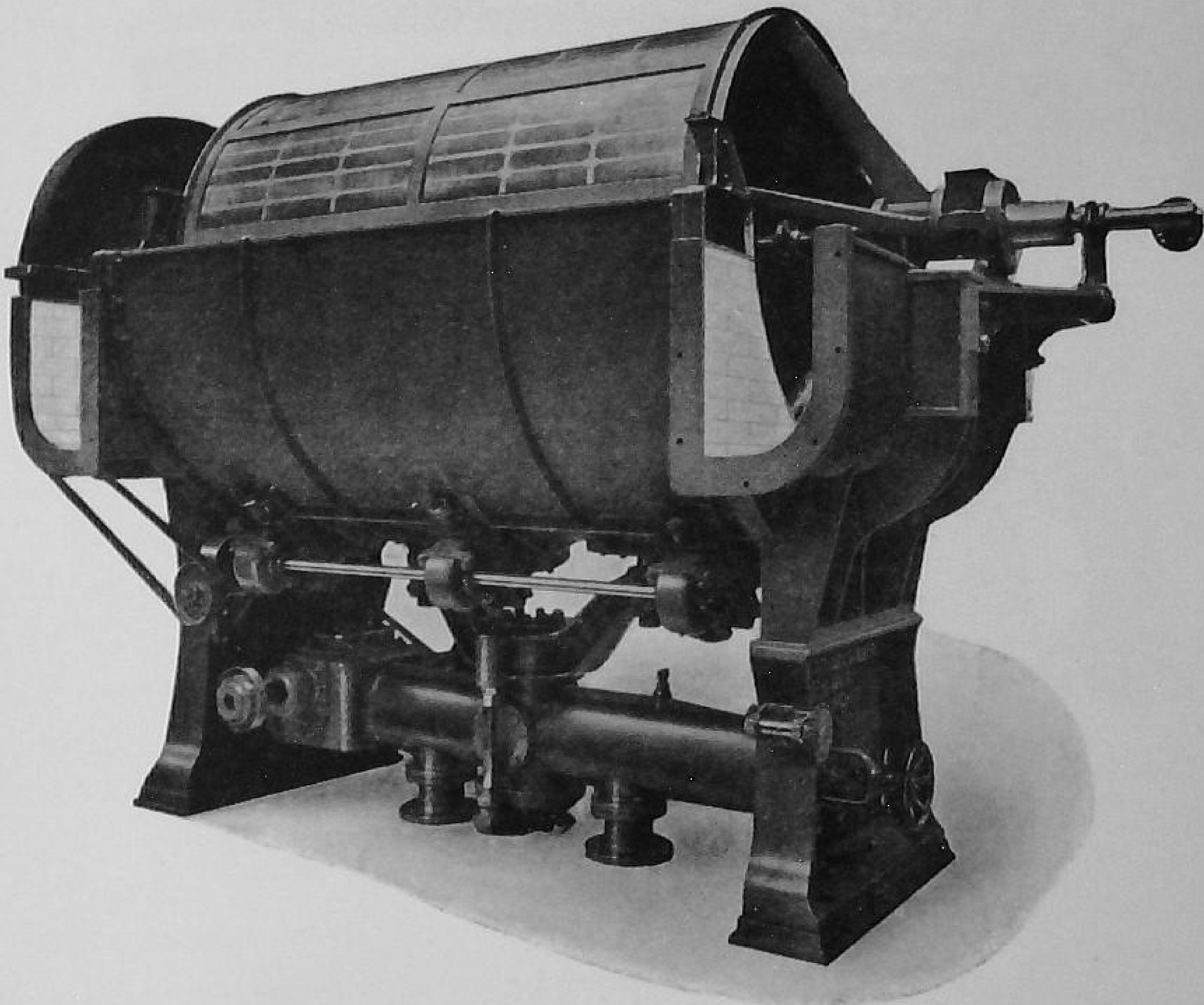
a vibrating brass diaphragm is situated immediately below the drum, and is actuated by two arms fixed to the vibrator and driven by a completely enclosed driving gear below. The stroke given to the vibrator may be varied at will while the strainer is working, and the vibrator may be removed from the bottom of the vat without disturbing the drum.

All the driving mechanism is entirely enclosed and works in oil, so that no water can get near it.

The pulp enters the vat below the level of the diaphragm, so that heavy particles and dirt are inclined to stay down in the lowest part of the trough. The stuff is pushed upwards against the lowest part of the drum, and passes through into the drum, from which it is poured out at the ends into the chute, which takes it to the breast box.

A strong shower of water is played against the slits at the top of the drum to clean it. This strainer is giving universal satisfaction, and possesses distinct advantages over most of the other inward-flow strainers, not the least of which is its freedom from a large collection of exposed working parts, belts, etc.

On of the latest strainers, and one which is giving great satisfaction in mills using short-fibred stock, is the Bird screen (Fig. 95). This is a large

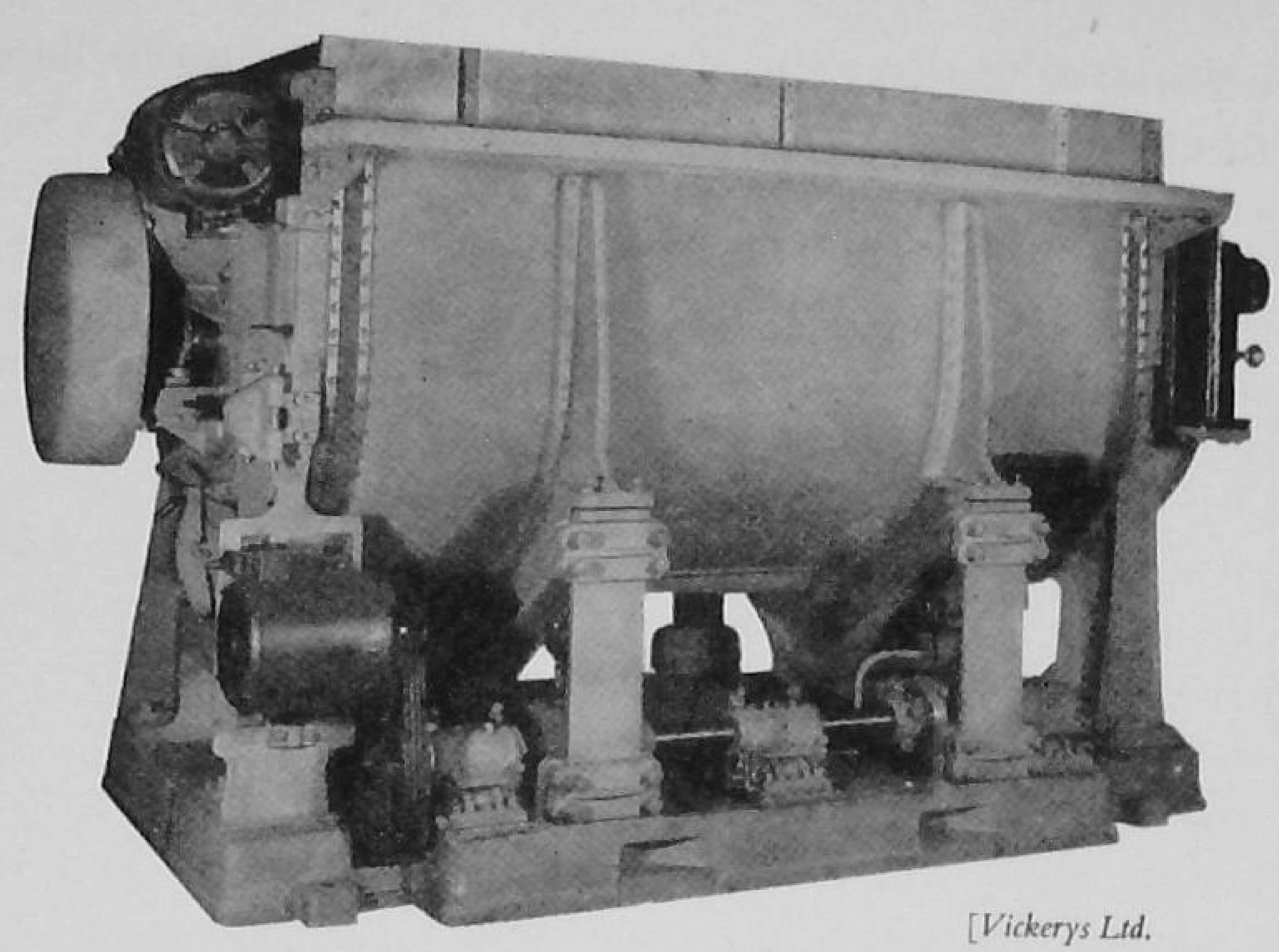


[*James Bertram & Sons Ltd.*

FIG. 94.—THE 'LEITH WALK' FULL-DRUM INWARD-FLOW REVOLVING STRAINER

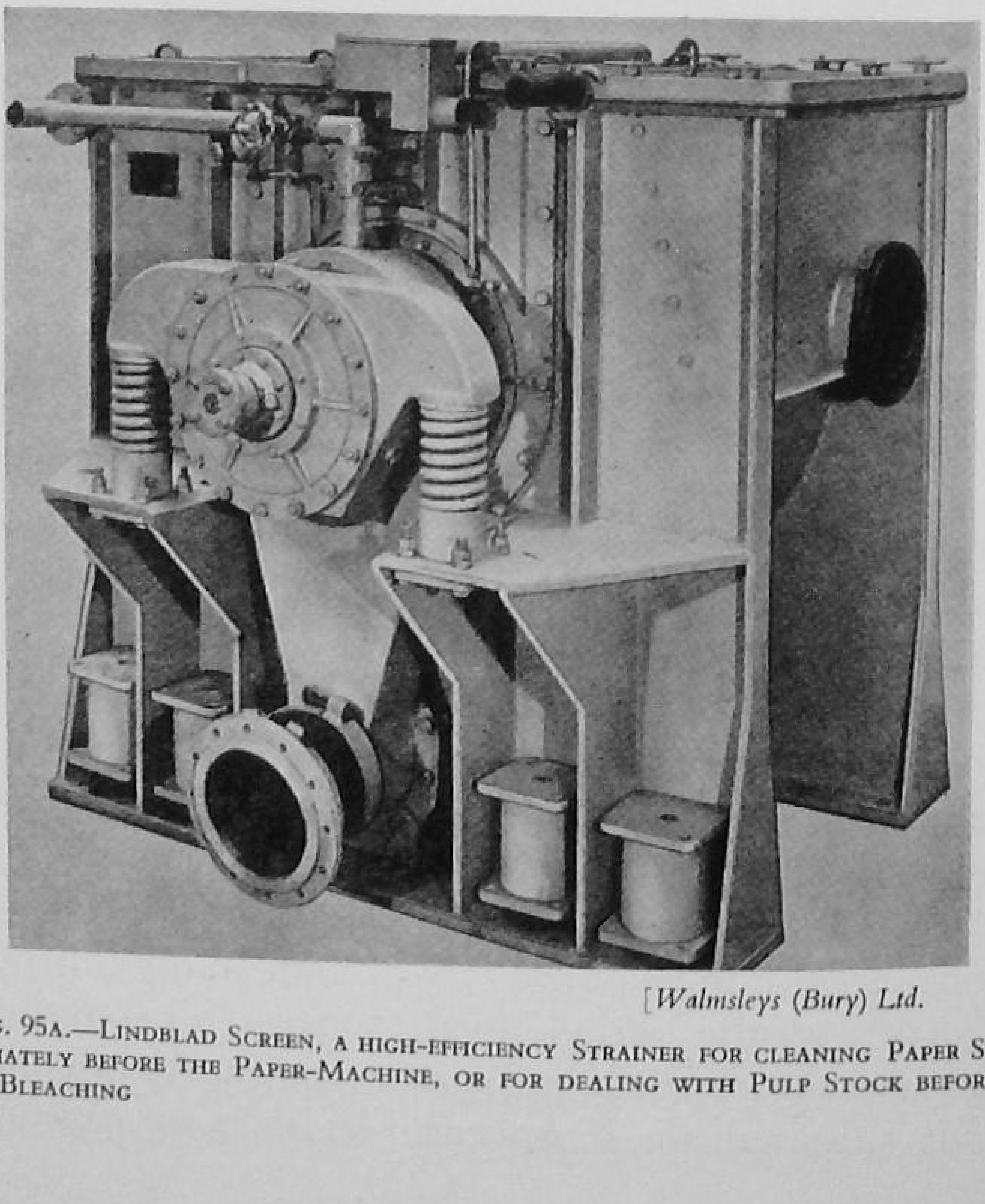
inward-flow strainer capable of passing a very large amount of stuff. The vibrating motion in this strainer is given to the whole vat, the drum revolving without shake, and no vibrating diaphragm being necessary. The body of the vat rests on semicircular brackets which are attached at one end to a spring, like the wire-frame spring support of a Fourdrinier wet end; the other end of the bracket is pivoted to the shake arm, which is actuated by a rod connecting to an eccentric shaft. The moving vat is connected to the fixed parts by a rubber connexion.

The stuff runs into the strainer from above and flows against the revolving drum, passing through the slits to the inside and thence out at the ends to the breast box. There is no violent action about the vibrating movement as in the case of the 'Leith Walk' and Banning and Seybold flappers, the shake given to the vat being easy and effective. It is claimed that only 25 per cent



[*Vickerys Ltd.*

FIG. 95.—THE BIRD SCREEN



[*Walmsleys (Bury) Ltd.*

FIG. 95A.—LINDBLAD SCREEN, A HIGH-EFFICIENCY STRAINER FOR CLEANING PAPER STOCK IMMEDIATELY BEFORE THE PAPER-MACHINE, OR FOR DEALING WITH PULP STOCK BEFORE OR AFTER BLEACHING

of power is required to drive this strainer compared with the diaphragm or vibrating drum type.

The plates are interchangeable. The strainer drum is closed at one end and discharges stuff at the other, and double packing strips are used to make the joint between the drum and vat, to prevent the mixing of screened and unscreened stock. There is a spray pipe at the top, and the water and loosened stuff are caught in a winged trough.

Auxiliary Strainers.—In almost every mill auxiliary strainers or 'back knotters' are used to deal with the stuff rejected by the machine strainers, and they do not usually receive as much attention as they should, either from the machineman or those in authority. The idea of the auxiliary strainer is that it should deal with all the lumps, and heavy stuff rejected by the machine strainers, and also with any scum which may run over, and with the water used to clear the slits. All these contain valuable paper-making material or chemicals, such as size, alum, etc., and if they can be recovered there is a great saving and also a reduction in the mill effluent.

This strainer usually consists of an ordinary flat jog strainer, with a fine cut plate, and it is often placed away in a corner at the back of the other strainers, 'out of sight and out of mind'. It should be placed in a prominent position whenever possible, so that the machineman may see that it always receives proper attention, and that others who pass may also see it.

In the case of rag stock, the heavy uncleared lumps and strings which gather in the trough of the strainers, together with the top scum, containing rubber, wood, etc., and the water from the spray pipes, should all be run into it and strained. A good many of the lumps and strings will be broken up, especially if plenty of water is used, and will pass through and into the back-water system, to be used again.

The rubber and pieces of wood and other light particles will float, and can be scooped off periodically, and thus, besides the great saving which is effected, valuable additional straining is also achieved.

The Watford Engineering Works have given a great deal of attention recently to the production of an efficient auxiliary strainer, and this works very well on fine rag stock and printings. This strainer (Fig. 96) consists of a cast-iron trough, and the strainer plates, which may be either flat or curved, are suspended from a shaft which runs in a tube, thus preventing the leakage of any oil from the plummer blocks. A 'tremor' motion is imparted to the shaft, which passes on the 'dither' to the plates. The strainer works very efficiently and is easily cleaned, as the straining portion tips up and exposes the plates. If it is desired, the strainer can be made to work on the 'inward-

flow' principle, the strained stuff being passed out through a flexible tube to the back-water pump. In this latter type the heavy stuff remains below

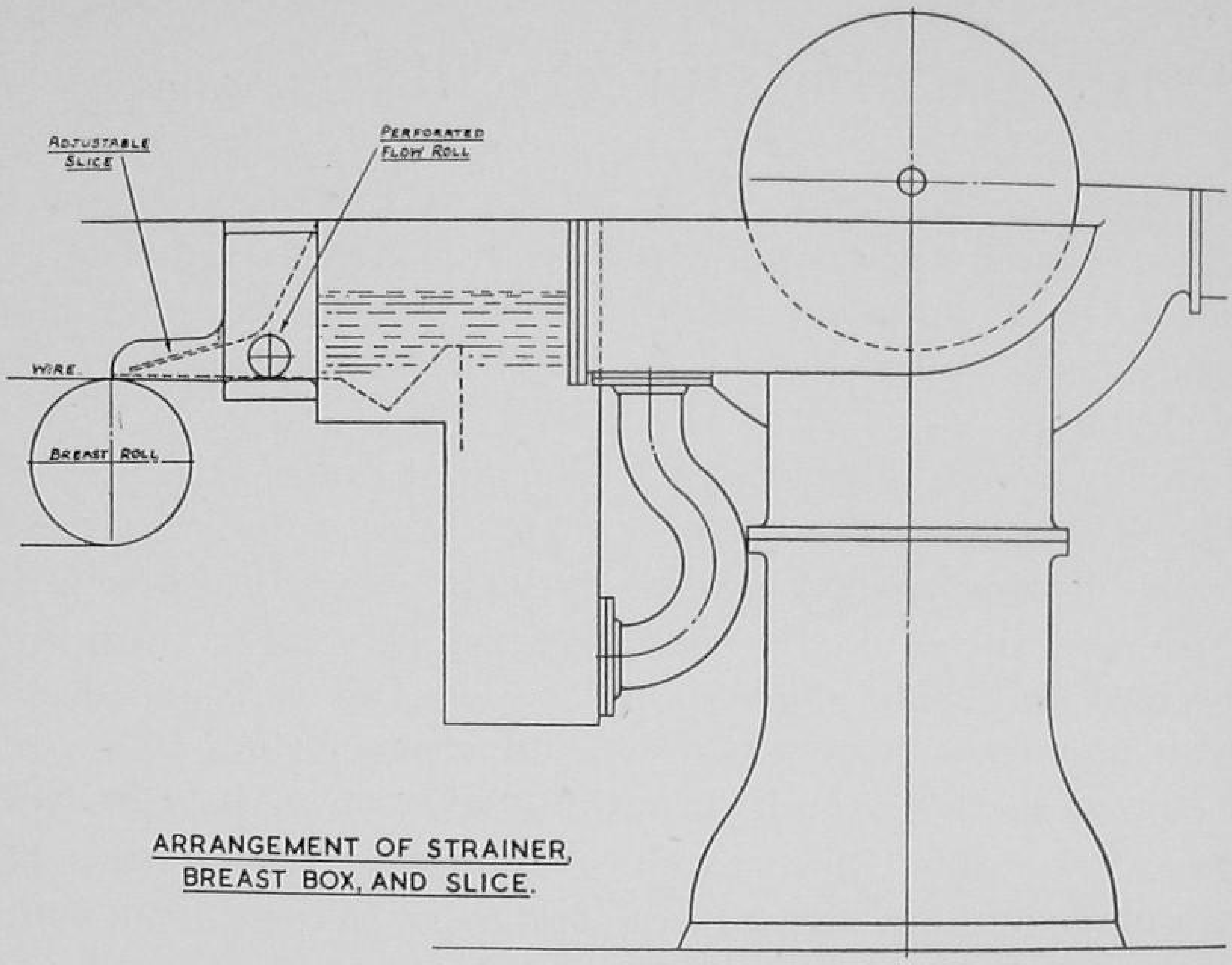


FIG. 96.—SIMPLE TYPE OF BREAST BOX, FREE FROM BAFFLES, ETC., AND WITH SHORTEST POSSIBLE PATH FROM STRAINER TO PROJECTION SLICE

the plates in the bottom of the vat, and can be washed out periodically with the hose-pipe.

This strainer, although primarily designed as an auxiliary strainer, is being used successfully in many mills as an ordinary strainer for the stuff itself.

A very satisfactory auxiliary strainer for dealing with rejects from the main strainer or screen is a small size 'Leith Walk' inward-flow strainer. This, of course, is exactly the same as the big main 'Leith Walk' strainer, works in exactly the same way, and will run for very long periods without any attention.

A further development in dealing with the 'bleed off' or rejects from the main strainer is the use of a small high-speed refiner, and where the rejects consist of nothing but knots of fibres, and where there are no rubber or impurities to deal with, this is a very satisfactory way of recovering what the strainer rejects. The thin stream of stuff bled from the strainer is passed through the high-speed refiner which pumps it back to the mixing box, having cleared the knots and rendered the stuff fit to be returned for use on the paper-machine. This development seems to have been carried out principally in the United States, and it is understood to be giving very good results.

CHAPTER XVI

THE FOURDRINIER MACHINE (*continued*)

Connecting Pipes and Chutes.—The height and situation of the strainers usually decide whether the stuff is run to the breast box through pipes or open chutes. Open chutes are easier to clean, but where pipes must be used they should be of copper, have very smooth interiors and be easily taken apart for cleaning.

Dirt or any rough surface inside the pipes causes clumps of fibres to form. This is very often the cause of a great deal of broke, as these lumps show up very plainly as clear specks or spaces when the paper is finished. For the same reason all chutes must be kept very clean, with no ragged wood or scale, and inside edges should be bevelled or rounded.

It is very important that the stuff which has passed through the strainer or screen should be got with the least possible delay on to the wire, with as few obstacles as ever possible. Many machines have what we consider to be far too elaborate arrangements of breast boxes, and many of these could not possibly be used for rag stock on account of the tendency of such fibres to collect and build up into lumps which are continually breaking away and getting on to the wire. It is very desirable that the strainer should be as near to the breast box as ever possible, that any pipes should be of ample size to take the stock at the maximum output of the machine, and that everything with which the stuff comes in contact, from the time it leaves the strainer until it is on the wire, should be absolutely smooth and polished.

Excellent results can be obtained with a very simple breast box such as that shown in the illustration (Fig. 96). The main object, of course, is to get a completely steady and absolutely level flow right across the machine as the stuff passes under the slice on to the wire. The shorter the flow from the strainer to the wire, the less likelihood there is of any settling out of fibres and loading, which always causes an ugly sheet, and makes it difficult to maintain regularity across the width of the machine.

The Breast Box.—This is an oblong box extending across the width of the machine. It receives the stuff from the strainers and, overflowing along its whole length, discharges it equally over the breast board. Some machines receiving the stuff from low-level pipes have a series of holes in the bottom of the box. These are connected by smaller pipes to the main stuff pipe. The stuff then flows over the edge of a board on to the breast board. This board

is sometimes the cause of clumps of fibres forming in the stuff, especially if its edge is badly trimmed or dirty. The best form of box is V-shaped, whether the stuff falls into it from above or enters at the bottom.

The consistency of the stuff should be equal at the sides and the centre. Where it enters from a series of holes in the box, from one side only, the side of the machine where it enters has always the closest and clearest water-mark, owing to the finest fibres coming first over the edge. The longer and heavier fibres are flung to the other side, and the machineman is often puzzled to know why he cannot get a uniformly made sheet all across the machine.

The whole object of the breast box is to keep the fibres in suspension in the water, and to prevent them from coming together and forming lumps, or settling down, and to ensure an even flow on to the wire, and that all stuff is of equal consistency across the whole width of the machine.

From the breast box the stuff passes on to the breast board, and thence to the apron, or the projection slice. Where an apron is used some sort of connecting device is necessary to bridge the gap from the stationary box to the oscillating board. This may be accomplished by having the breast box at a sufficiently high level to allow the stuff to pour over the lip into the recess of the breast board. Another way is to bridge the gap with a strip of some strong flexible material which is fixed to both the stationary and the moving board by a continuous strip of metal and countersunk screws.

The material called 'moleskin' used to be very popular for the purpose, but its hairy surface makes 'drags' in strong papers. Thin and flexible leather may be obtained for the purpose, and if carefully fixed and used will be found to give good service for about twelve months before having to be renewed. In an emergency, a strip of good old rubber apron will answer the purpose.

The connecting strip should be examined for any cracks or holes when the machine is shut—about once a week—otherwise a loss of stuff may occur and remain undetected for a long time. It should be kept wet over the week-end.

From the breast board the apron receives the stuff and delivers it to the wire. The apron should conform with the following requirements: it must be thin, tough, smooth, non-elastic, composed of a material that will not rub off in pieces or flakes, or wear to a frayed surface, or edge, or wrinkle up with changes of temperature or humidity. Fibrous materials, varnished or waterproofed, are sometimes used, but these cause trouble, since threads at the extreme edge where the material is worn by the wire make streaks and lumps, especially in tinted papers and blues and azures. Even one cotton fibre streaming from the edge, and so small as to be almost invisible, will do this.

The life of the apron depends in a great measure on whether there are many changes of deckle and the care which is taken by the machinemen in making these changes; also on the method of making a reasonably water-tight joint at the first deckle pulley. The best method is the roller apron. The apron is taken underneath a brass plate just inside the pulley and rolled up on a small cylinder which is kept at tension by a cord and weight. This plate is made to be adjusted as close as possible to the wire, leaving just enough space to let the wire run without nipping the apron. The latter is fixed to the breast board by a brass strip and countersunk screws, except for that length at both sides of the machine that is allowed for the maximum and minimum breadth of deckle. A slip of brass, bent to a knee shape, keeps the loose part down on the breast board, and may be pressed down to make a water-tight joint. When drawing out the deckle, the roll on the cylinder must be eased off to let the apron pay out freely and the plate and brass slip put carefully down after the change is made.

When putting the deckle into a narrower width of sheet, the plate and slip should be raised up and the cylinder helped to roll up the loose apron. The reason for this is that, generally, the weight of the slices and pulleys will cause the cross-bars to sag down a little as they are moved towards the centre, and this must be allowed for, or the apron will be nipped between the plate and the wire.

When the brass plate is fixed or cast in one piece with the deckle pulley fittings, the upright pillars of the cross-rods may be raised. There is usually provision made for this adjustment by having the pillars threaded and held by two nuts.

It is generally found necessary to pack a handful of soft stuff at the outside of the apron on the breast board to prevent fibres coming out and getting under the deckle straps. This arrangement is very efficient and gives a sharp, clean deckle edge to the web of paper. Another method is to fix the apron down on the breast board all across its length and arrange a piece of well-worn old couch cover on the brass plate, so that the empty space between the deckle pulley and deckle strap and the apron is closed up. This projects in a knee shape about $1\frac{1}{2}$ inches over the apron, and allows the deckle to be changed without so much risk of tearing the apron, but is not very effective and requires very skilful handling to give a clear deckle edge.

When changing deckles, the apron ought never to be strained or pulled very strongly, or it may then refuse to lie flat. Stuff will then run under the raised part and make continuous streaks or rolls in the paper. A very good plan for getting the apron to lie and remain flat is to utilize an old apron for supporting the new one. The old apron should be cut to about two-thirds of

its width and put on underneath and along the new one. This helps to bridge the gap between the lip of the breast board and the highest part of the breast roll, and takes a great deal of strain and wear off the top apron. The lip or wire edge of the apron must coincide with the centre of a tube roll, and all tube rolls under the apron should be kept well oiled and running freely, otherwise air will be drawn through with the wire, causing little holes or clear spots in the paper.

After being put on and once made wet, the apron should never be allowed to get dry; a trickle of water ought to run on to it during the week-end and when there is a shut long enough for it to dry up.

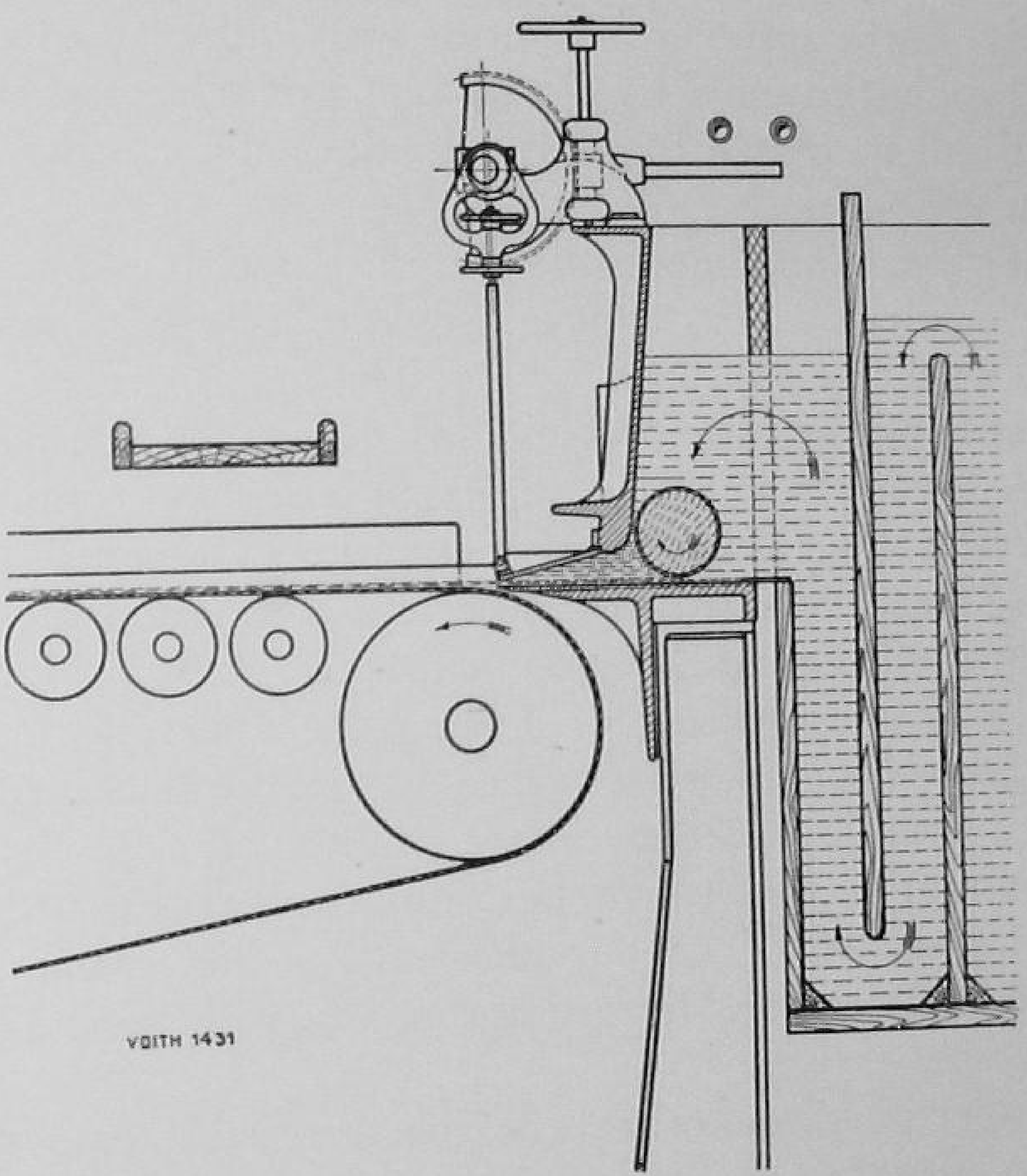
When shutting down, all fibres and any dirt, sand, etc., must be washed off with the hose-pipe from the apron, breast board and connecting devices, towards the breast box. If allowed to get on the wire, it will often be found that these hard substances will pass to the couch rolls and stick in the cover or the guard and score or cut the top couch jacket. A very soft brush or piece of soft felt ought to be sufficient for cleaning the apron, if cleaning is done as often as it should be. This is one of the jobs that the machineman should do himself, and it need only occupy a few minutes. It is of the greatest importance that, from the strainers to the apron, every part that the stuff comes in contact with should be kept spotlessly *clean* and, what is even more important, perfectly *smooth*. A good apron will, with decent handling and care, give a year's service.

When a projection slice is used no flexible material is required to carry the stuff from the breast box to the apron board, and in most cases no apron is required. The stuff runs out from the projection slice and falls directly on to the wire.

The Slices.—There may be one, two or sometimes three of these. The usual type is of brass, $\frac{1}{4}$ inch in thickness and from 4 to 6 inches broad. They are each in two pieces, overlapped in the centre. The overlap is adjustable; it can be raised or lowered by screw pins, and permits the slice to be shortened or lengthened according to the width required. The edge nearest the wire is tapered to a fine edge, which is not sharp, but smooth and slightly rounded. In the making of paper the slices are of more importance than the average machineman realizes. Their first purpose is, of course, to spread the stuff so as to have a uniform make and weight all across the web. Many machines have only one slice, but it may be asserted that two are required, since we find that, with only one, it is necessary to check the first rush of the stuff with a board or wooden slice, so as to let it get to the slice in a more 'settled' state.

Sometimes slips of lead are hung from a bar across the breast board for the

same purpose, but these are a great trouble to keep free of accumulations of stuff. Therefore it is far better to have properly constructed slices.



[*Masson Scott & Co. Ltd.*

FIG. 97.—VOITH SLICELESS FLOW BOX

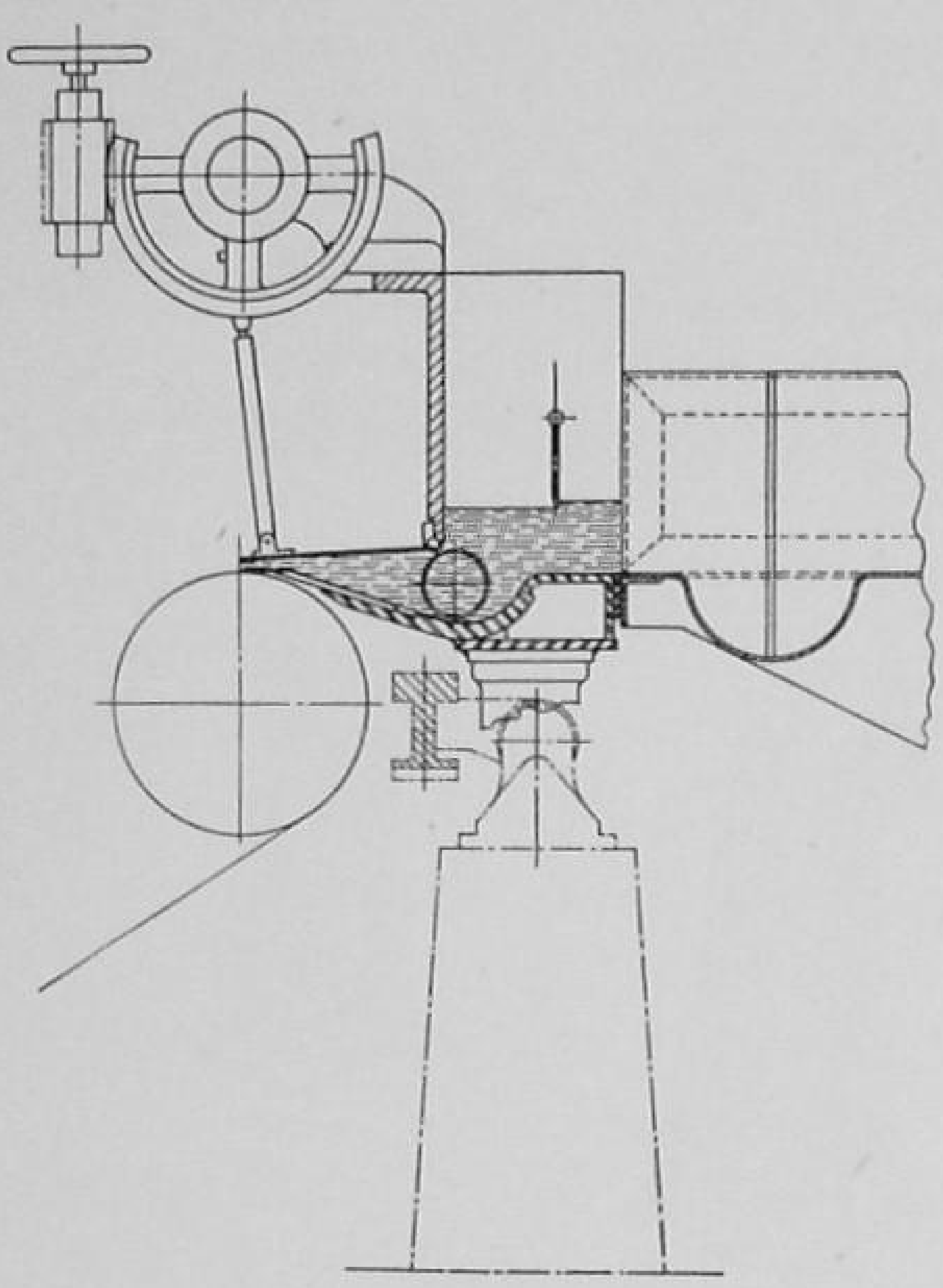
The first is used, as stated, to check the first rush of stuff and keep back froth, the second to spread or level the sheet. The latter slice should coincide within $\frac{1}{8}$ inch with the edge of the apron. The reason for this and the use of the slices in 'making' the paper will be dealt with later on.

The adjustable sliceless flow box or, as it is now usually called, the projection slice has been designed to eliminate the old type of slices entirely, and also to dispense with the apron. It has been, in its various forms, a great success, and has eliminated many of the troubles experienced by the machineman with the older types of slices.

The principle of the flow box is illustrated clearly in Figs. 97 and 98. The head of stuff is maintained above the adjustable gate, through which the stuff is projected on to the wire in a smooth and continuous stream of the same width as the deckles.

The stream of stuff is under perfect control and can be easily adjusted to

suit any class of sheet, speed or substance. It bridges the small gap between the wire and the fixed lower lip of the discharge gate, so that neither the usual apron nor slice is required, and nothing but stuff comes in contact with the wire. The upper lip of the discharge gate is adjustable in such a way that the thickness of the stuff stream can be regulated either as a whole, across the full width of the sheet, or locally at any point on the sheet, where for some cause or other there may be a thick or thin place.



[*Masson Scott & Co. Ltd.*

FIG. 98.—PROJECTION SLICE AND BREAST BOX WITH SUNK POSITION FOR FLOW ROLL AND KNIFE SLICE IN BREAST BOX

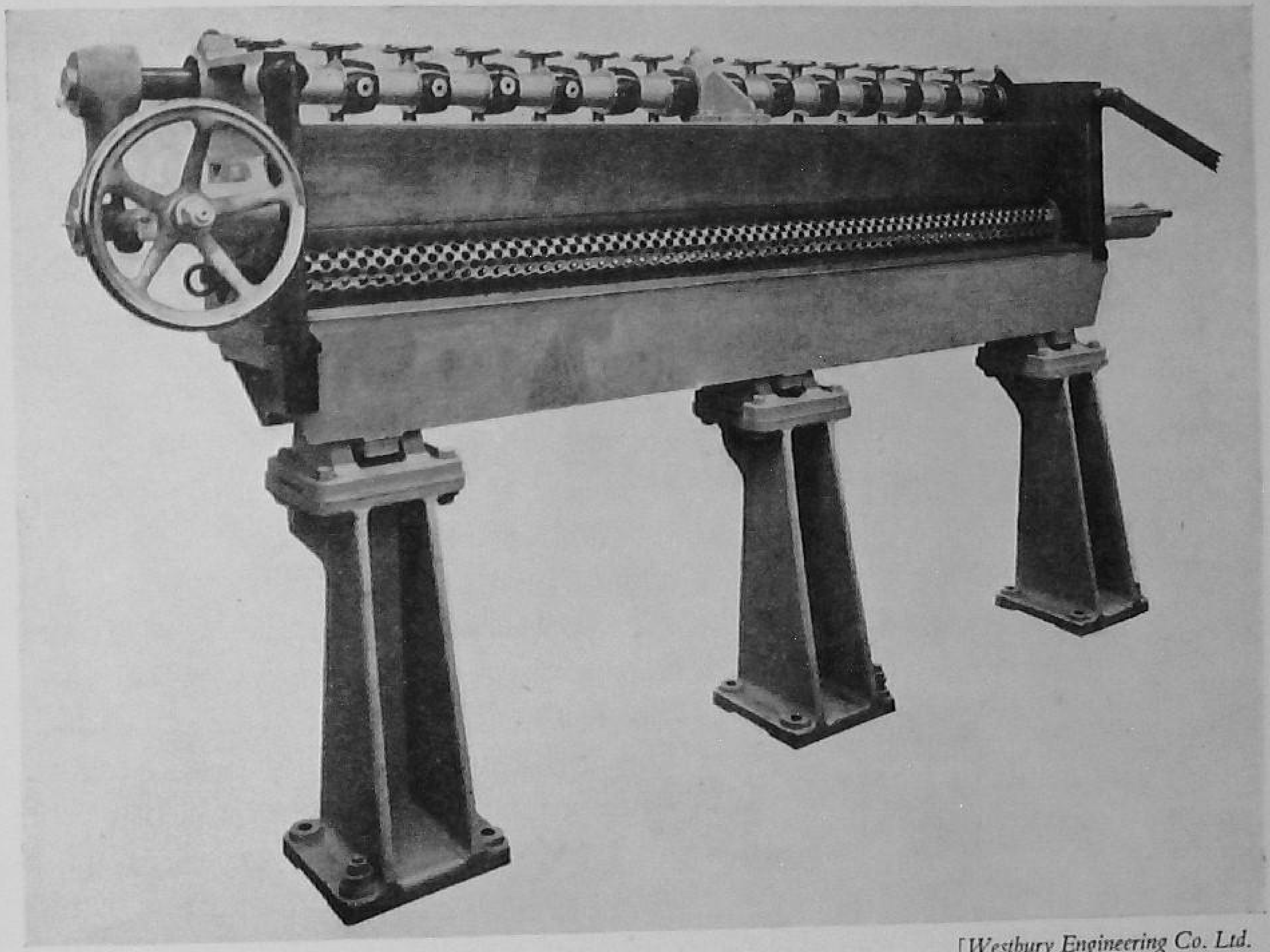
The whole stuff gate may be opened or closed at one operation by turning the hand wheel on the front side. The local adjustment is done by vertical screw-threaded spindles secured to the flexible bronze upper lip of the discharge opening (Figs. 100 and 102). The adjustments are simple, and can be made by the machineman while the machine is running, and without having to use pieces of paper on the slice or bits of lead on the apron, or any other troublesome and unsatisfactory makeshifts.

A revolving, perforated copper roll, called the flow roll, seen in the illustrations (Figs. 99 and 101), is placed just behind the discharge opening, and helps to release air bubbles; it also keeps the fibres in a state of agitation, and therefore properly suspended in the water, and ensures a very even flow.

The absence of an apron altogether on fast machines, and the use of only a very narrow one on slow machines, saves a great deal of drag on the wire, apart from dispensing altogether with the numerous troubles caused on all machines by aprons, no matter how well they may be fitted.

There is a great saving of wear on the wire, especially on very fast machines, where a very heavy head of stuff has to be maintained behind the usual high slices. No pond at all has to be supported by the wire when a flow box is used. This fact gives also greater 'making' length of wire to the machine, as the stuff has more room to felt and begins to drain at the breast roll itself. The box keeps back the froth which continually forms behind the slices, and comes away with variations in the amount of water or state of the stuff from the beaters. It is very easily washed down when

changing, and if good sprays are kept in operation above the stuff behind the box there is very little trouble from air bells.



[*Westbury Engineering Co. Ltd.*

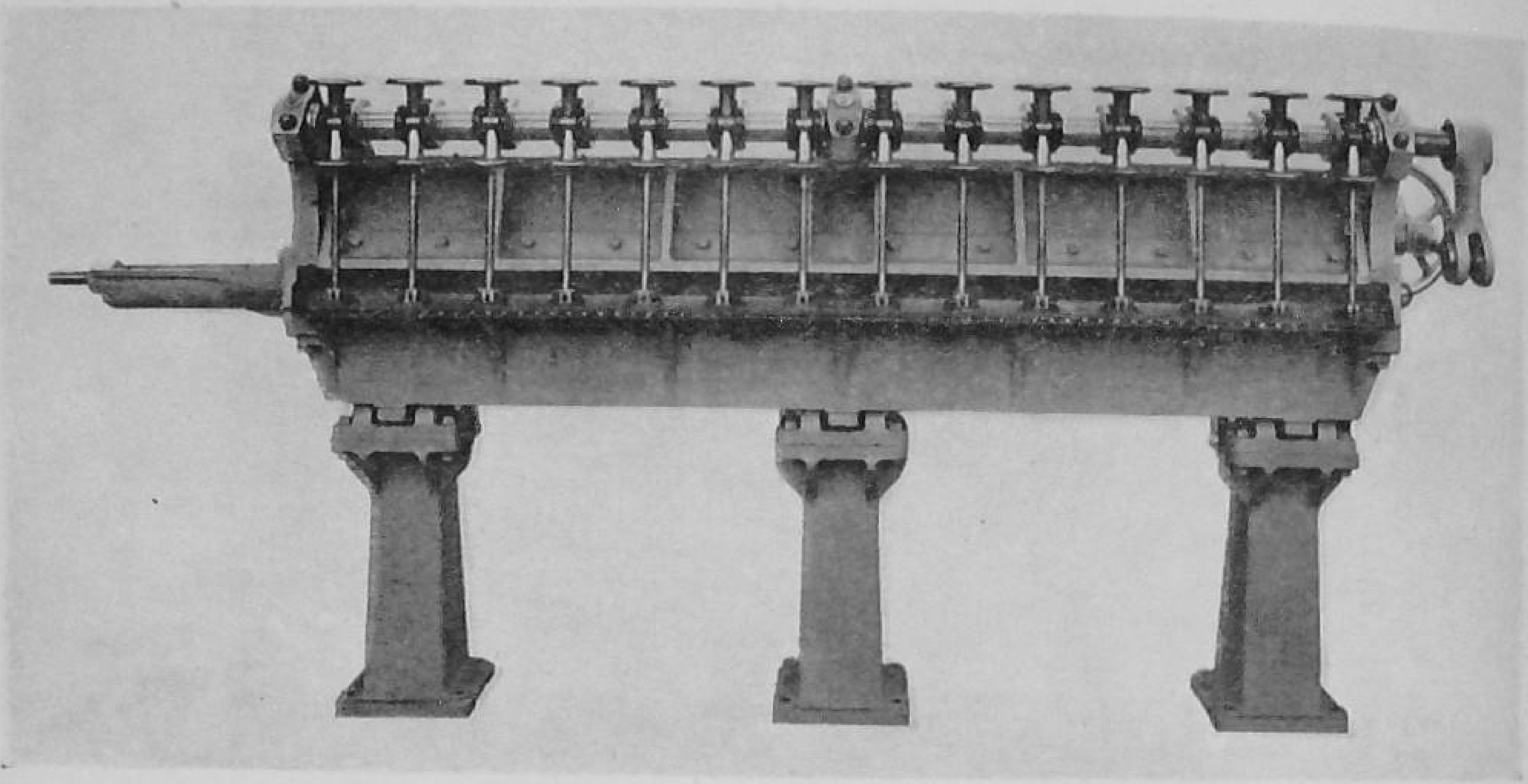
FIG. 99.—WESTBURY PROJECTION SLICE, REAR VIEW SHOWING PERFORATED ROLL

The flow box is giving great satisfaction on many machines at present, and is especially satisfactory on fast machines, although it is equally effective on slow and 'fine' machines.

The principle of getting stuff satisfactorily on to the wire from the breast box, is to cause it to flow on at the same speed as the wire is travelling, except when special features are required, such as cloudiness in a ledger paper ; it thus becomes a question of adjusting the weight of the head of stuff to give a pressure sufficient to force the stuff forward at the correct speed. Until the introduction of the projection slice very little attention had been paid to this important subject, and in most cases the stuff came slowly forward until caught by the wire, and it was then whisked suddenly forward and rolled into waves and generally disturbed, when it should have been coming under the action of the shake and been properly felted together.

It can therefore be said that the use of the projection slice helps very

considerably in forming a better and stronger sheet. The amount of stuff for a given substance and speed is, of course, still regulated by the stuff and



[*Westbury Engineering Co. Ltd.*

FIG. 100.—WESTBURY PROJECTION SLICE, FRONT VIEW

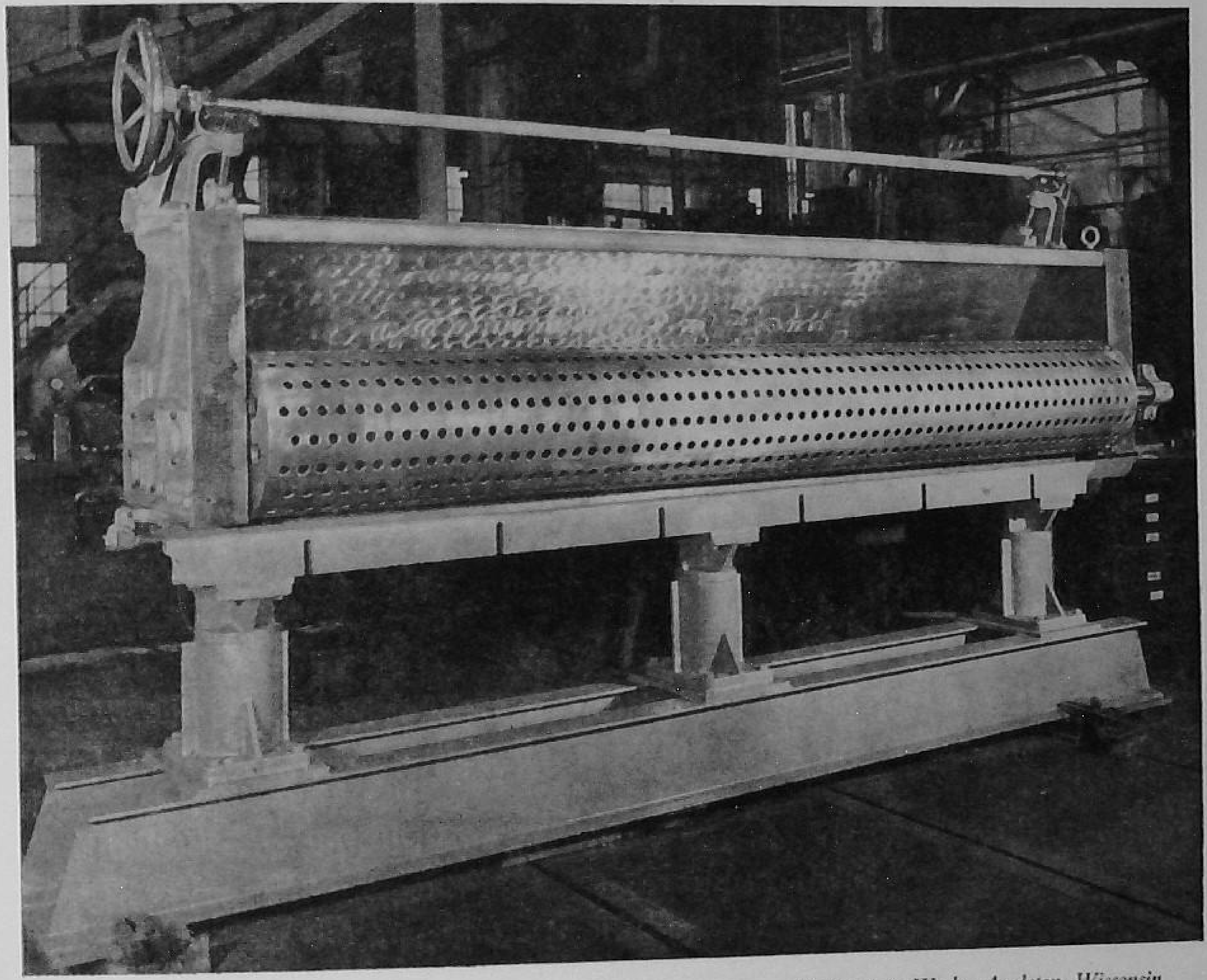
back-water taps, but the head of stuff behind the box, to give the required speed of discharge on to the wire, is regulated by the opening of the lips of the gate.

The correct adjustment of the gate and head of stuff must be found by the machineman himself, according to the substance he is making and the speed of the machine, just in the same way as he had to find these adjustments with his slices. The adjustment, however, is far more easily controlled, both for the whole width of the machine—by turning a wheel—and for any individual unequal patches by screwing the adjusting spindles up or down. It has one great disadvantage, however, in that it cannot be used satisfactorily where there are many changes of deckle width. When a slice is used it should be high, so as to allow a deep pond to be worked; 18 inches is not too high for a machine running up to 650 feet per minute, and very much higher for fast speeds and free stuff.

The Wire.—The wire is the most delicate and expensive part of the machine equipment. It may be described as a sheet of fine wire gauze, joined by a seam to form a continuous band.

The fineness of the wire, its texture and mesh, are made to suit the class of paper for which it has to be used, and the speed at which it is to be run. The wire is made of bronze of various alloys of copper, tin, etc., and these are

varied by the makers to obtain a combination of strength, durability and wearing qualities.



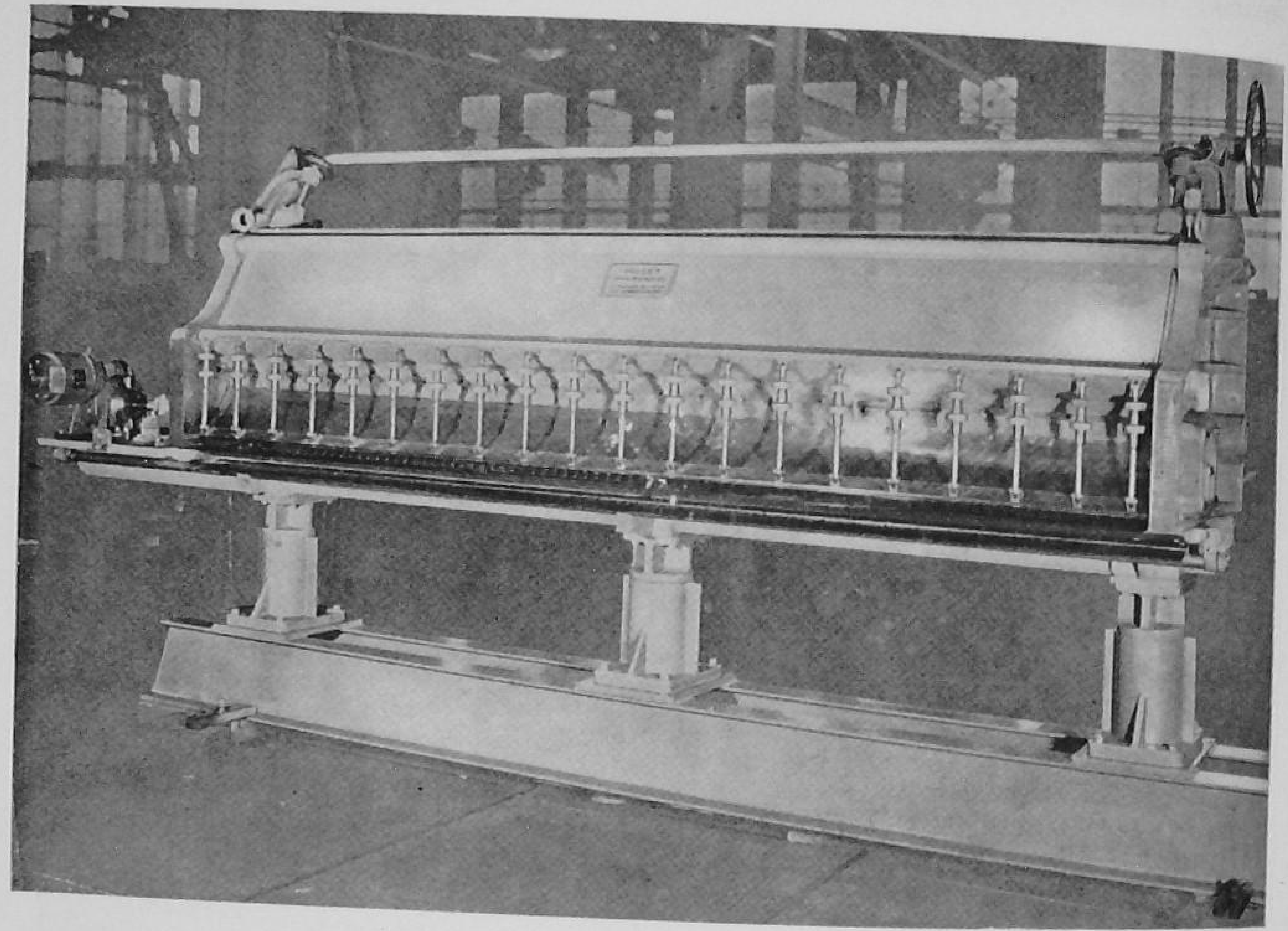
[Valley Iron Works, Appleton, Wisconsin

FIG. 101.—PROJECTION SLICE WITH LARGE PERFORATED FLOW ROLL AT REAR OF SLICE

Machine wires may be obtained in a wide range of mesh and quality, and in various types of weave. The old weave seems now to be giving place to long crimp, flat-warp and twill types of weave for which various advantages are claimed, and the wire-makers are continuously experimenting with different weaves, to give strength and wearing qualities, and smoothness to the under side of the sheet of paper, so that the surface of the under side may be as nearly as possible equal to that of the top side.

Great praise is due to the energy and extensive research work of the paper-machine wire manufacturers, who do their utmost to give the paper-makers exactly what they want, and enormous strides have been made in the improvement of wires and in the method of making the join during the

last few years. At this stage it is desirable to outline briefly some of these developments.



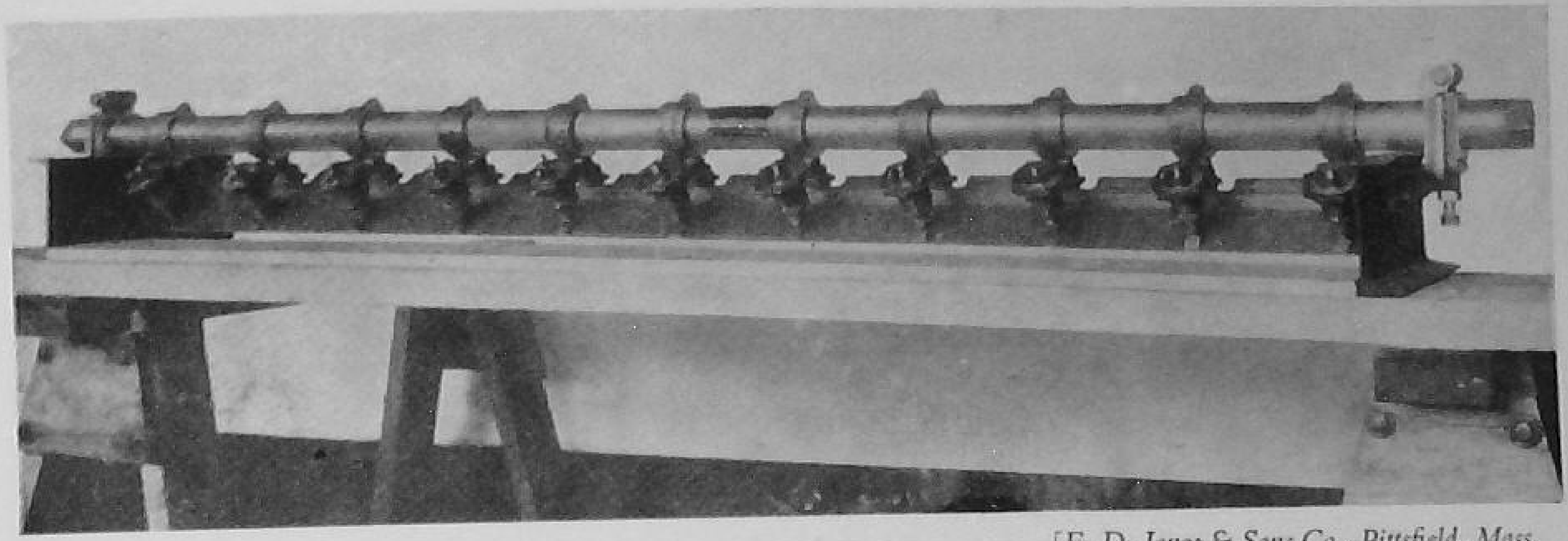
[Masson Scott & Co. Ltd.

FIG. 102.—VOITH TYPE SLICELESS FLOW BOX, SHOWING FLEXIBLE LIP AND ADJUSTING RODS

The first radical change in the construction of paper-machine wires was the introduction of long crimp or twill weave. This was done with the object of increasing the life of the wire, and was first introduced for the manufacture of newsprint. It remained as such for a considerable number of years. The wire mark caused by this particular weave was different from anything previously known, and in a number of early cases was considered objectionable. Various improvements in the weaving, however, have modified this mark in the under side of the paper, and in nearly every case newsprint is manufactured over twill wires, certainly on the wide machines 19 feet and over in width.

Various developments and improvements of the twill weave permitted its application for the manufacture of finer papers, and various weaves are now on the market known under the different titles applied to them by their various makers, such as Superfine Quality, Flat Warp, etc., the object of these fine weaves being to present as many places of support as possible to

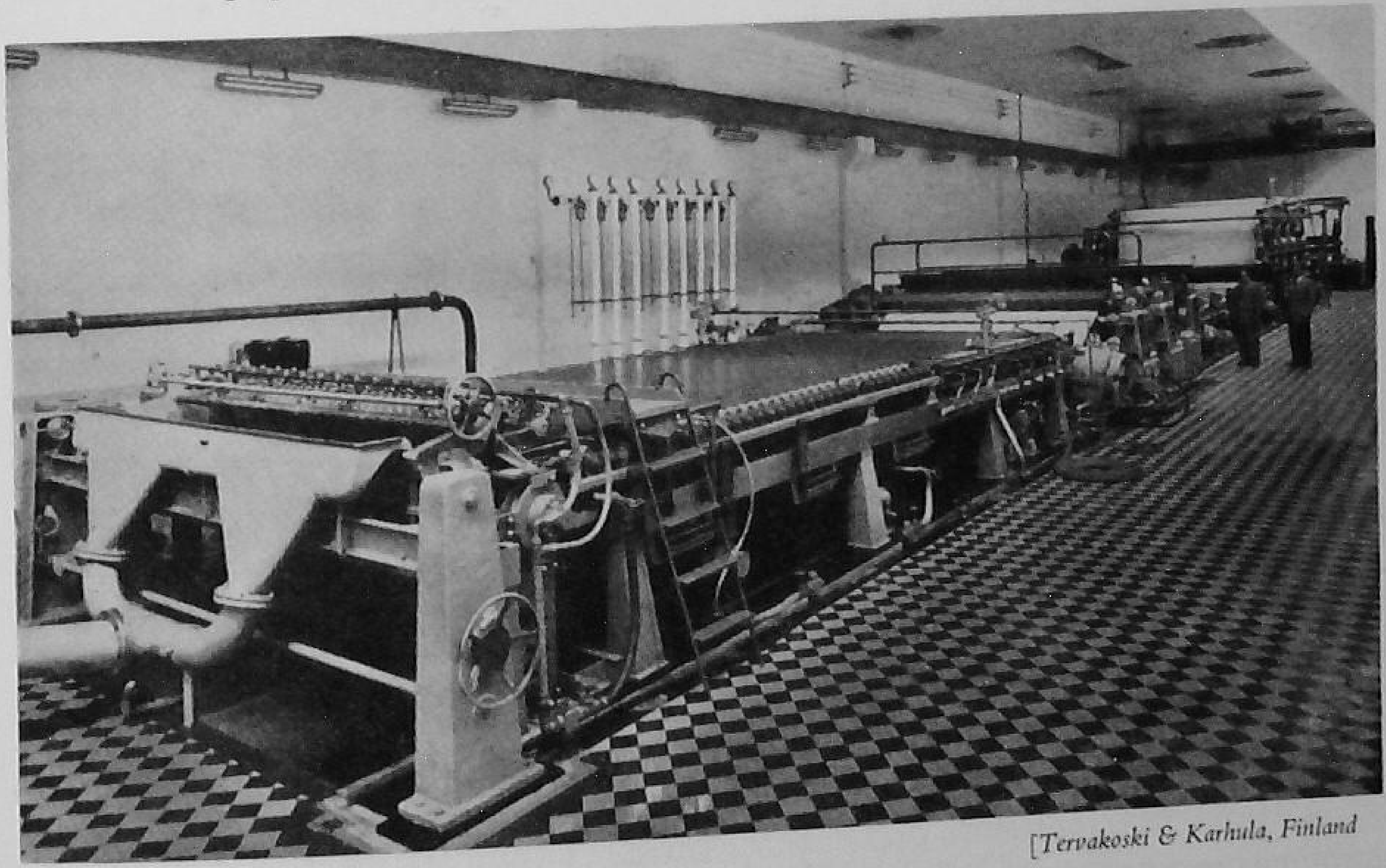
the under side of the sheet during formation, and so prevent any prominent knuckle imprinting itself into the web. The question of wire mark is no



[E. D. Jones & Sons Co., Pittsfield, Mass.

FIG. 103.—THE TEALE FLEXIBLE ADJUSTABLE PROJECTION SLICE

longer the source of worry that it used to be to the fine paper-maker, and in some cases in paper made on these new weaves it has been almost impossible for anybody but the expert to say which was the top side and which the under side. The paper-maker, therefore, who wishes to avoid wire mark must



[Tervakoski & Karhula, Finland

FIG. 103A.—WET END OF MODERN MACHINE FOR FINE PAPERS, SHOWING CLEAN AND ACCESSIBLE DESIGN

co-operate with the wire-makers to provide him with the most suitable formation of weave for his purpose.

Another very valuable attribute of these wires is the improved shape of hole. In the ordinary plain weave the hole is of a very oblong shape, whereas

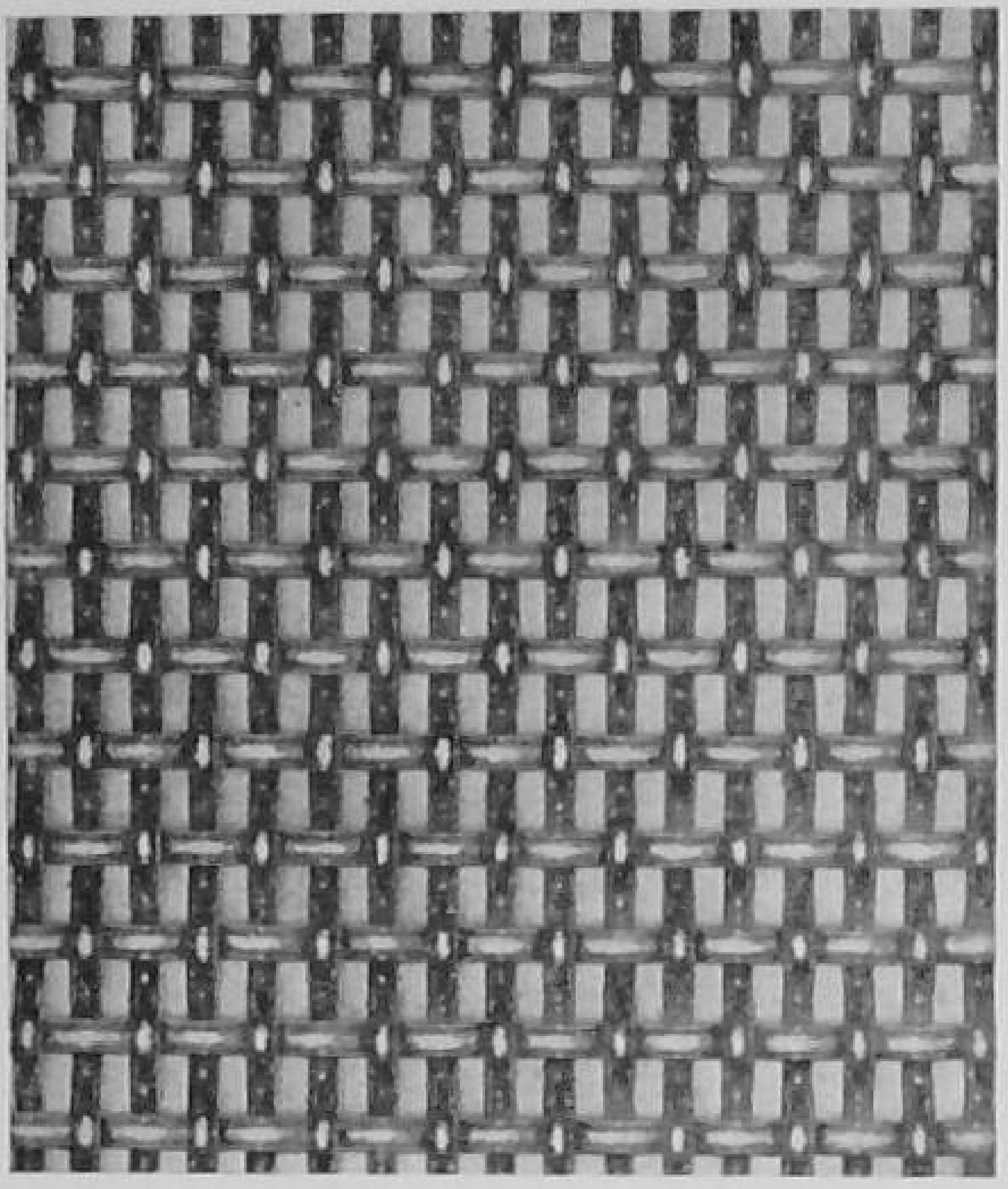
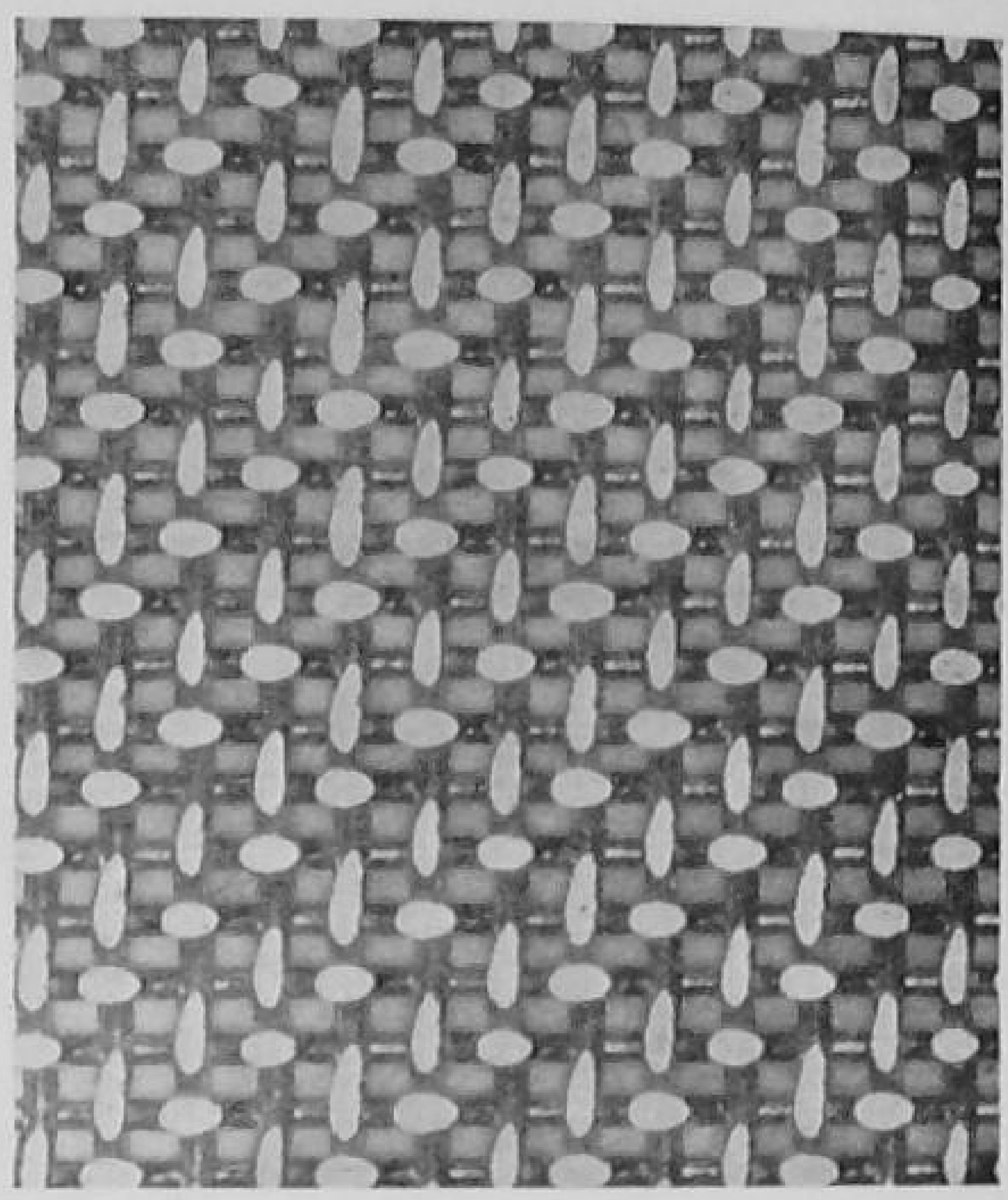


FIG. 104



[*United Wire Works Ltd.*

FIG. 105

FIGS. 104 and 105.—PHOTOGRAPHS AT THE SAME MAGNIFICATION OF PLAIN WOVEN AND SUPERFINE WIRECLOTH

with the newer weave it is very much squarer, with a consequent reduction in the loss of fine fibres. This can be readily seen by a comparison between Figs. 104 and 105, both of which are 72-mesh photographed at the same magnification, but No. 104 is the old plain weave and No. 105 a Superfine equal to 72. It is particularly interesting to note that the use of 90, 80 and practically all 76-mesh wires of plain weave has been discontinued in favour of these new weaves, with none of which it is necessary to go finer than 72.

It is not unusual, however, for mills making a wide range of papers, both of quality and substance, to keep to one mesh and to vary the furnish and beating to prevent 'wire mark', or to enable the paper to run on a fine mesh wire.

When there is more than one machine, it is more economical and efficient to use wires with different meshes and run on each the quality that is best suited to it.

The *length* of the wire depends on various circumstances, chief of which are the speed of the machine and the quality of the paper. It is obvious that the longer the wire the more water will drain from the stuff through the action of the tube rolls before it reaches the suction boxes. Hence for heavy substances and rag papers a long wire is indicated, to run at an

economical speed. On the other hand, if banks have to be made on the same machine, too little water would be carried to the dandy roll to have a good control of the water-mark. Therefore a compromise has to be made, and the length of the wire has to be decided by all the circumstances, including very often the space available. From 40 to 60 feet give good average results, with from 16 to 30 tube rolls, according to their size and the speed at which the machine is to run.

This question of length of machine wire has always been a subject of controversy among paper-makers, but before stating definitely what length of wire is most suitable for a machine making certain classes of paper it is necessary to take a variety of subjects into consideration.

Other things being equal, the machine on which very wet or highly fibrillated stock has to be worked will require a longer wire than one on which only free stuff is worked.

The reason for this is that the wire is simply a filter for removing the water and receiving the fibre deposit upon its surface. It is true that the sheet or web is formed on the wire, and that sheets of different formation and appearance may be made on the same wire by altering slightly the lateral movement of the wire frame and/or the amount of water in the stock, but the formation of the sheet—even of a very strong sheet—is accomplished in a very short distance along the wire. After the stuff has settled down—say half-way along the wire—no change in the position of alignment of the fibres appears to take place, and the wire is simply carrying the web along to the first suction box. There is something else happening, however—that is, the removal of water by each of the tube rolls. This water can be just as well removed by an extra suction box or two, so that the difficulty of a short wire can be easily overcome.

On those machines where a Voith slice is used it is no longer necessary to take up 2 or 3 feet of wire by covering it with an apron or pond of stuff behind the slices, so that this gives more actual paper-making length on the wire.

It must be remembered, however, that there is a tendency now to prevent water being taken out by the first few table rolls, in order that the effect of the shake may be brought to bear on the fibres while they are still floating in water which is not passing away through the wire. There is also a tendency for table rolls to be substituted by flat boards or smooth surfaces of stationary metal for the first 12 inches or more of the wire after it leaves the breast roll.

There are a good many fairly old machines running at the present time on which very strong rag papers are made, where great difficulty is experienced in getting the water out before the dandy and couch roll, resulting

in 'crushing' and spoiling of the sheet. Sometimes it is quite impossible to make the required sheet for the following reasons:

1. The stuff is too wet and the wire too short for water extraction, if sufficient water is put on to 'make' the sheet.

2. If water is put off at the stuff box the stuff is too inert and greasy to shake together properly when it reaches the wire. It will also be found that if water is put off, the stuff cannot be got through the strainer, especially if it is long as well as wet.

3. If sufficient water is put on to get the stuff through the strainer and to make the sheet on the wire, then there is too much water at the dandy and couch rolls. Heating the stuff will help matters, but in order to get over the difficulty permanently there are two alternatives only. Either to put in one or two more suction boxes, with *separate* vacuum pumps, or increase the length of the wire and the number of tube rolls.

Really wet, thick stuff, for strong ledgers, parts very slowly with its water, and *gradual but not too fierce* suction is necessary if the work is to be properly done.

The Seam.—This is the place where the two ends of the wire cloth have been joined, and whilst not so many years ago this was a source of worry and trouble to everybody connected with the use of machine wires, the enormous improvements which have been made in the construction of the seam due to the research work expended has altered the position entirely. Perhaps no one particular type of modern seam has any advantage over the others. Some are welded, others soldered, but those constructed in the newest manner with the latest available technique should be equal to the strength of the wire itself, nor should they make any mark in the paper, or if they do it should be the very minimum.

As a matter of interest a plan view (Fig. 106) is shown of one of the very early types of seams, and Fig. 107 of a little more modern seam, both hand-sewn. Fig. 108 is a modern welded joint; Fig. 109 is a soldered joint. It will be observed that in the welded or soldered joints there is practically no obstruction to the drainage.

There is, however, one condition which even welded or soldered joints will not withstand, nor for that matter any wire, and that is grooving or freezing to the suction boxes. This is a point which should be understood by every paper-maker, foreman and machineman who wishes to get the best results from his wires. By the term 'grooving' is meant that each individual warp wire as it travels across the boxes wears a channel into the top. If there are 60 warp wires, then there are 60 channels formed in the top of the boxes, which, if the trouble is allowed to continue, will have a formation like a

miniature piece of corrugated paper. Obviously when this condition has arisen it is impossible for the wire to travel laterally across the boxes, an

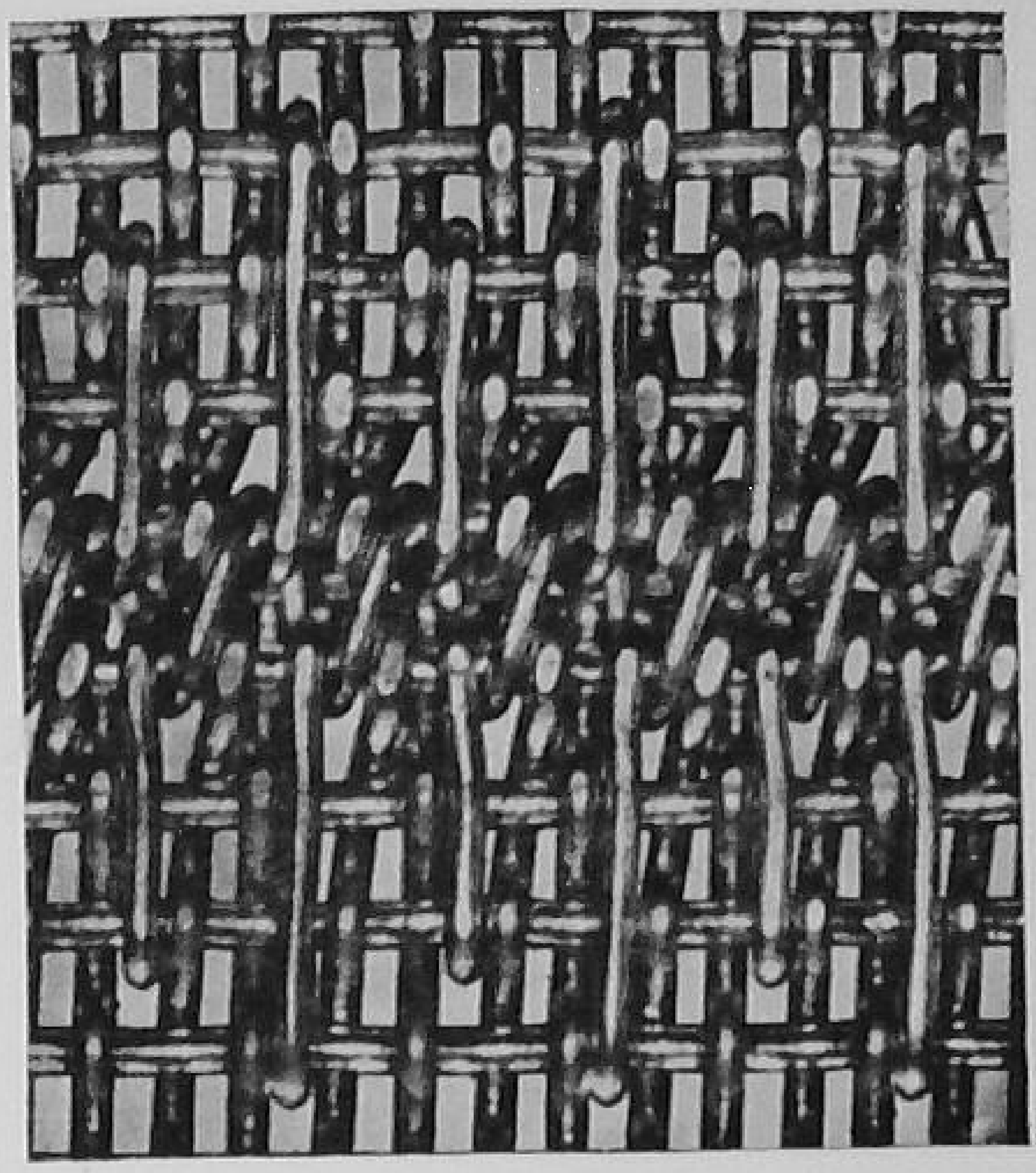
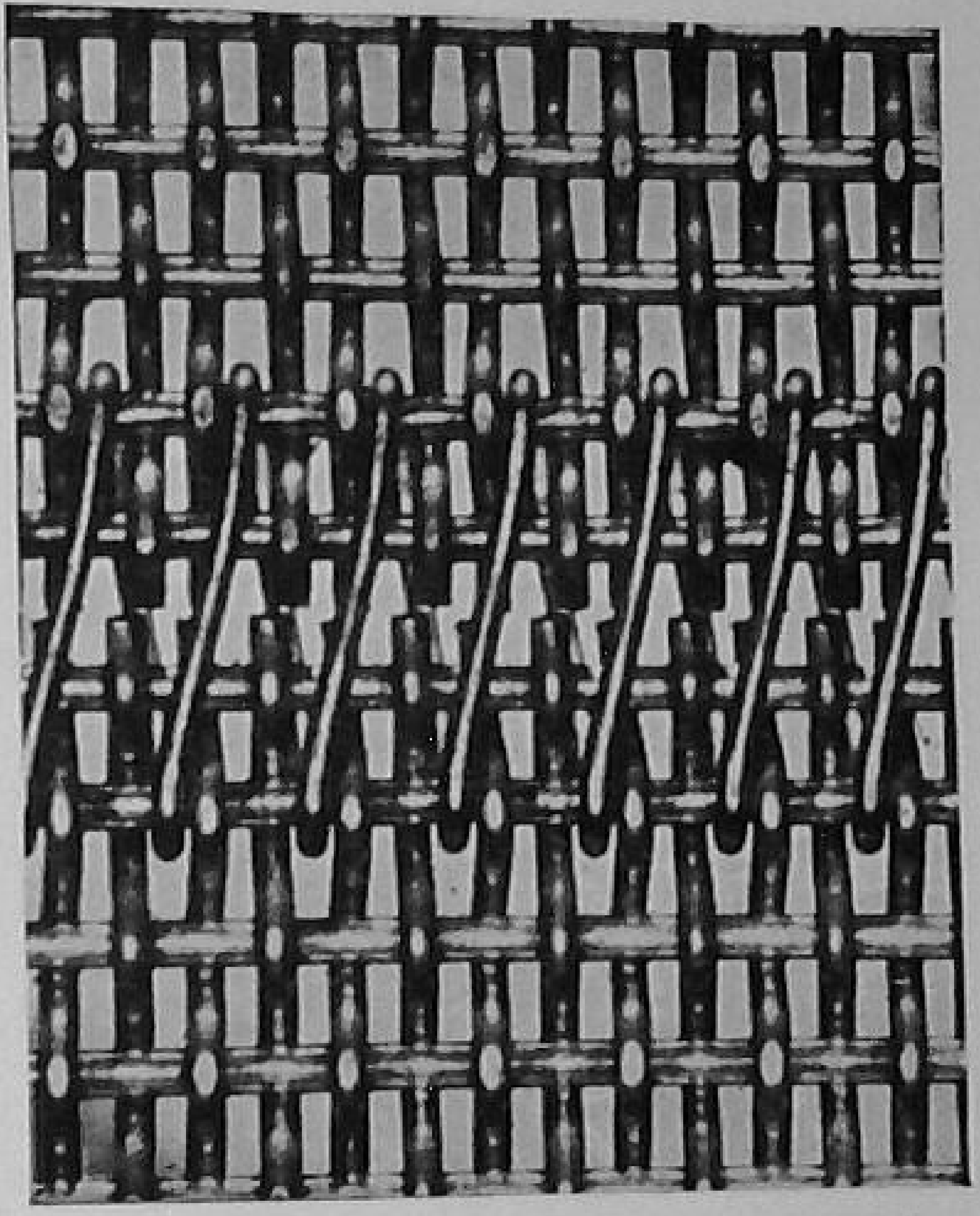


Fig. 106



[*United Wire Works Ltd.*

Fig. 107

Figs. 106 and 107.—Photographs of Hand-Sewn Seams

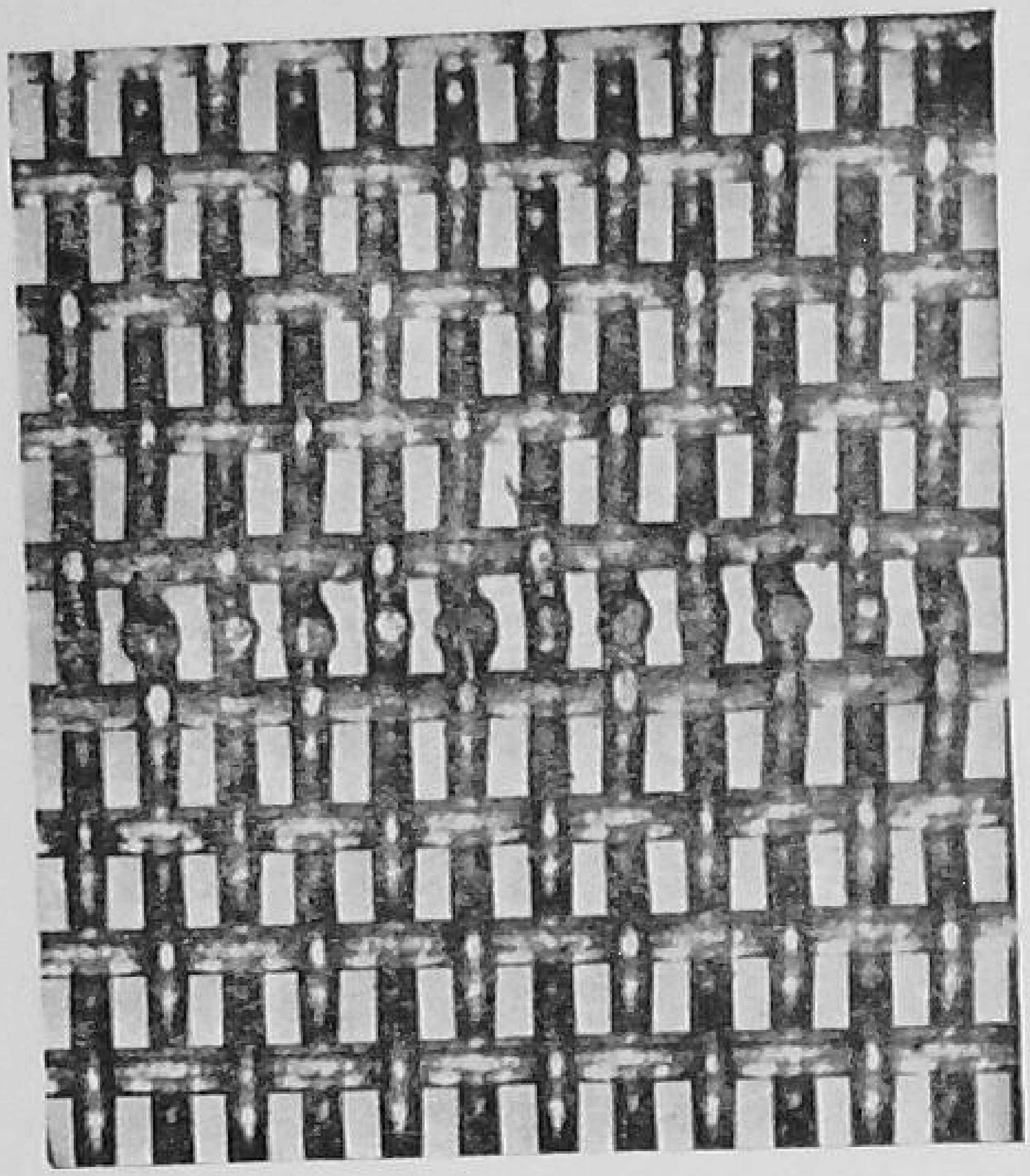
Fig. 106 shows how drainage is interfered with in the old type of seam, while Fig. 107 shows a more modern sewing, in which the drainage is much improved.

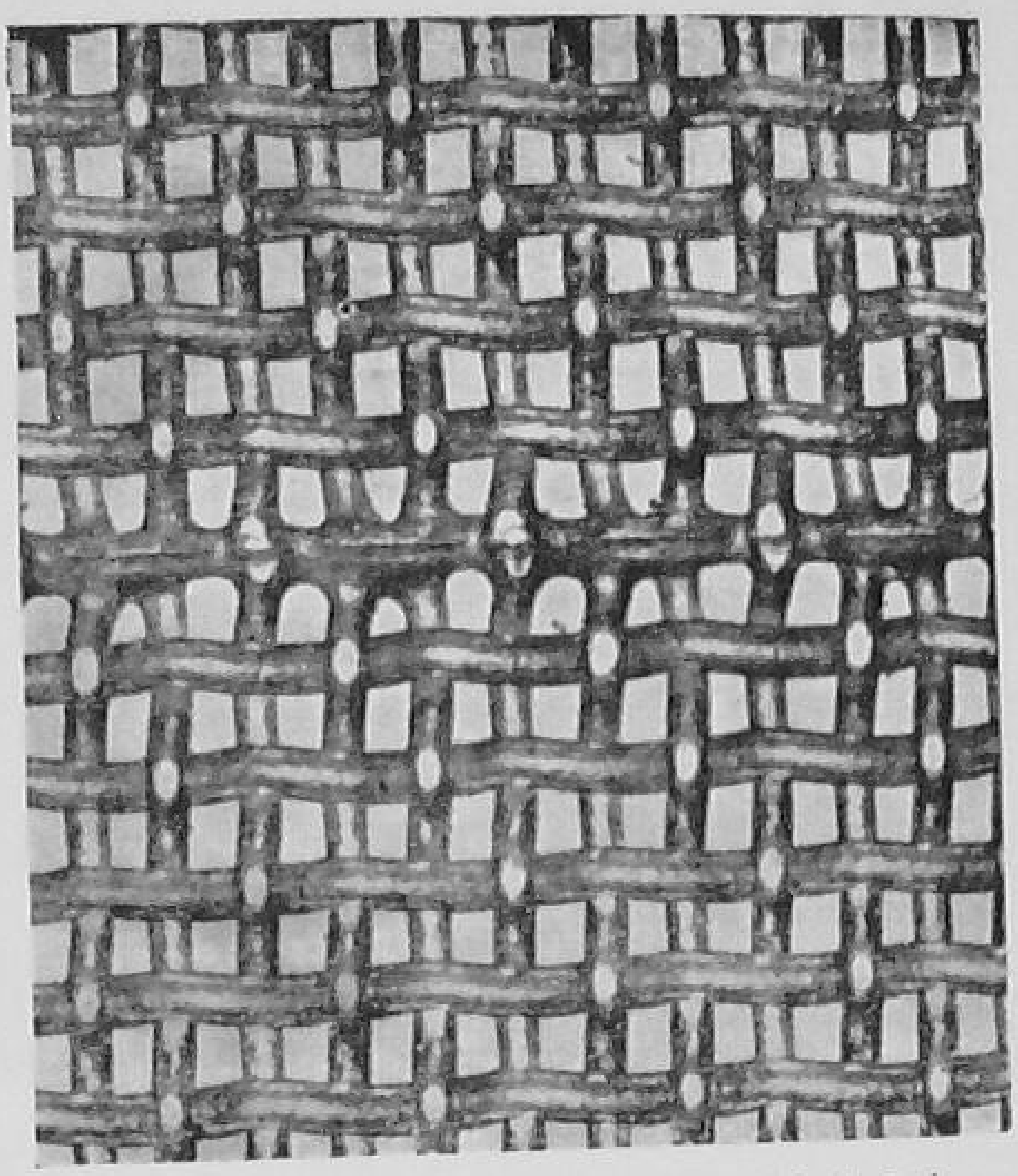
essential factor to the successful running of a paper-machine wire. It will be readily understood that when the slightly thickened blobs of the weld at the joint meet the grooves they will not fit into the grooves, as they are larger in diameter than the wire which formed the groove. This consequently raises the wire a small fraction off the top of the boxes, making a momentary break in the vacuum, with a consequent mark in the paper. This is also applicable to a soldered joint. Not only does this objectionable feature wear out the joint, but it also wears out the whole wire by causing grooves in every under-side warp knuckle as it tries to travel to right or left across the boxes.

Fig. 110 is a plan view of the under side of a hand-sewn seam which has been allowed to groove, and Fig. 111 is a plan view of the under side of a twill wire similarly worn.

Close observation of the wire when in operation should readily reveal when it is grooving. In the first place, a knock can often be heard as the joint hits the front of the suction boxes, but apart from this the under side of the wire shines and glistens very brightly as compared to a wire running in the normal manner.

The remedy, of course, is to shift slightly the offending box or boxes, or if this fails to overcome the trouble, then it may be necessary to remove the suction boxes from the machine and face up the tops.





[United Wire Works Ltd.

FIG. 108

FIG. 109

FIGS. 108 and 109.—WELDED AND SOLDERED JOINS

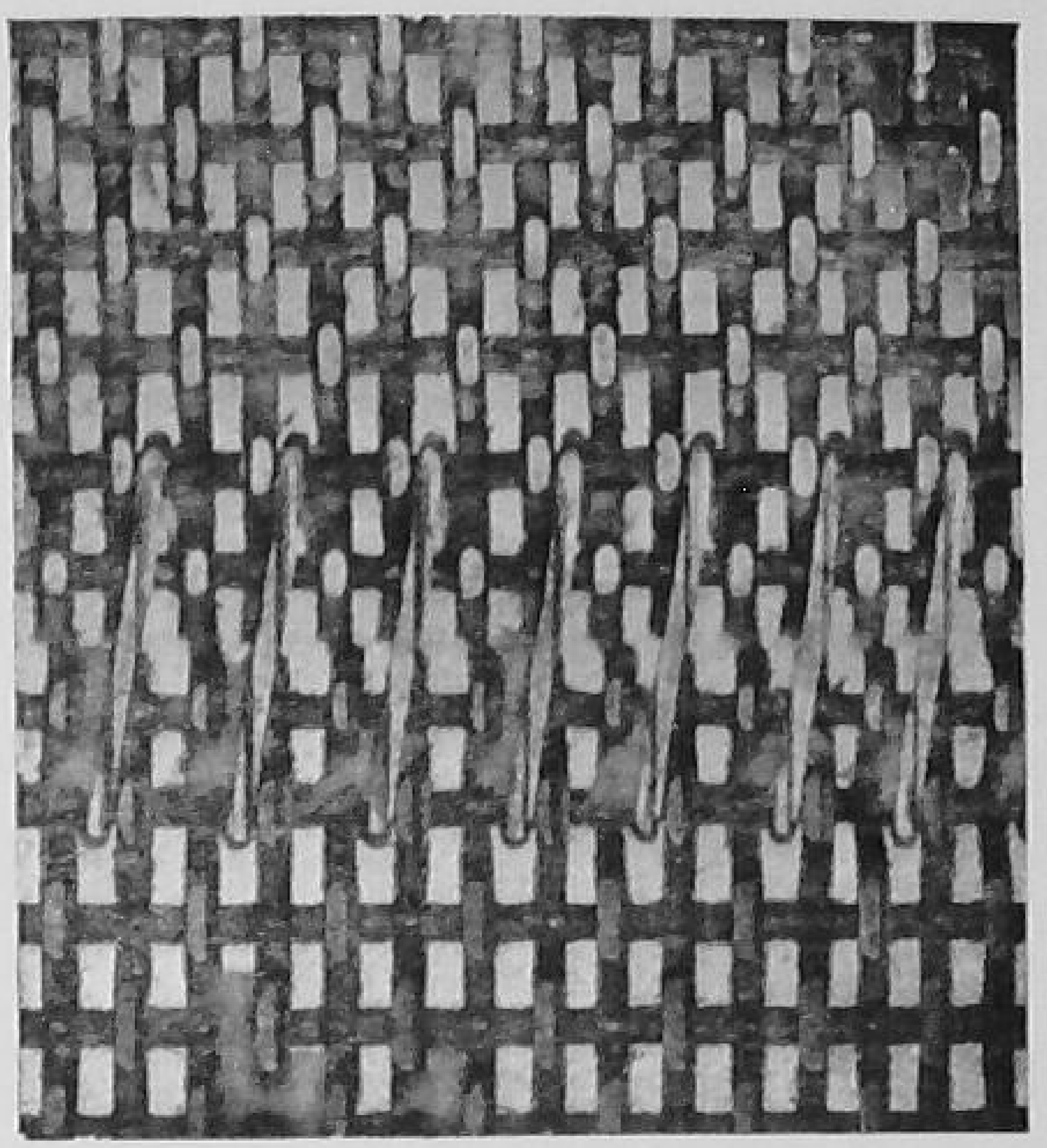
Machine-wire manufacturers have their own methods of overcoming this objectionable feature, but up to date it appears that whilst they have been successful in 99 per cent of cases, there are still the odd few which give trouble, and when they do it is trouble indeed unless immediate steps are taken to counteract the fault.

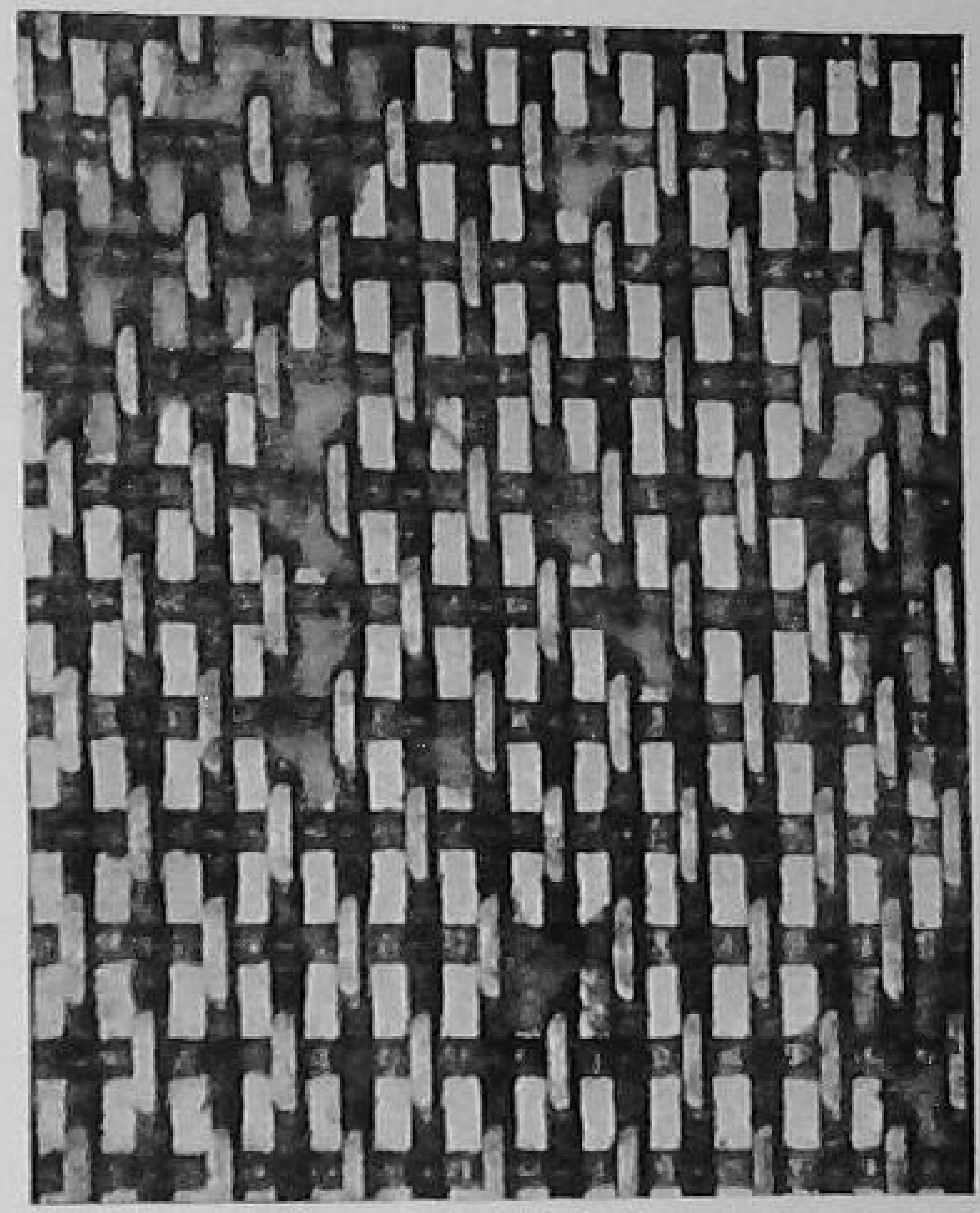
The life of a wire is the length of time it runs or, more correctly, the weight of paper made during that time. But it can readily be understood that no definite time or weight can be calculated on, since a machine making thin papers will wear out a wire with less output than one making heavier substances with the same width. The factors that influence the life of a wire are of two kinds. First, the care taken of the wire by the machinemen and their skill in use, and accidental damage; secondly, those agencies which are constant and unavoidable.

In the first may be placed the putting on of the wire when new. Without going into all the details of putting a new wire on the machine, we will just mention some of the items where damage may be done and how to avoid it.

The box containing the wire must be carefully opened. The screws which fasten the lid should be withdrawn entirely by the screw-driver and

removed. The wire will be found packed with straw or fine wood shavings, and jammed endways by means of two pieces of wood nailed to the ends of





[*United Wire Works Ltd.*

Fig. 110 Fig. 111

Figs. 110 and 111.—Photographs of the Under Sides of Hand-Sewn Seam and Plain Woven Wire, both of which have been allowed to groove

the rollers or poles on which it is wound. It is lifted out of the box and laid on a long table, on which there are no other objects, such as spanners, nails, etc. The two pieces of board are then knocked off—a smart blow with the palm of the hand will suffice—and the rollers firmly held until both ends are clear. The covering wrappers, on which will be found the 'certificate' (number, date, etc.), are ripped off with the fingers, never with a knife or other hard tool. There will be three poles or rollers, two of which are in the centre of the web; the other is inside, and protects the loose end, and all three are firmly bound in position at the ends. The binding is cut while the third pole is held in position by one man at each end, and no attempt must be made to move the position of the pole until both ends are loose. It should then be laid gently on the table, thus unwinding the first turn, and withdrawn. When doing this, the machineman should superintend and make sure that it is slowly and evenly drawn out, and that nobody knocks the end in the process. Though the lid of the box may be unscrewed, it is safest to leave the wire in the box until the machine is quite ready for its reception.

The most difficult part of the work is then proceeded with. Two men with strong hands and wrists lift the wire, by means of the ends of the two remaining poles, slowly upwards from the table, and the loose end swings

free and must not be touched. It is advisable to steady the wire and assist in supporting its weight by placing two men opposite the loose end, with the palms of their hands under the roll. All obstacles should be removed from the floor, in case a man should trip. The wire is held in line with the bottom couch roll, which is supported by a jack or block near the centre and stands pointing clear of the frame or brackets of the machine. The roll of wire is then unwound far enough to allow the loose end to form a loop big enough to receive the couch roll. This loop must be opened out by a machineman standing inside the frame, but there should be another man at the opposite side of the wire acting in concert and keeping the wire tight from side to side; otherwise, if it is attempted to open out the loop at one side only, the wire will be buckled and the mark will be permanent. In this position the wire is advanced as far as the supporting block, when an extension is put through the loop and takes hold of the couch-roll spindle. The weight of the roll is then taken with this extension shaft, the block removed and the wire slowly and carefully carried over the roll. It will be found that if the latter is jacketed the edge of the wire will not slip over it freely, but will be held by the hair of the cover. This must be watched for and guarded against. Once safely on the bottom couch roll, there is not much danger of damaging the wire if ordinary care is taken in putting through the breast and other rolls.

The wire must be supported by two poles when putting in the 'tube rolls'. These poles must be held at the same height and tension, and when moved forward as the tubes are placed in position it should be done slowly and in the same parallel, or the wire may be buckled or wrinkled. When all the rolls are in position and the suction boxes are levelled, the stretch roll should be allowed to tighten the wire by its own weight only.

Then the machinemen should examine all the arrangements and see that no pieces of wood from the save-alls or suction boxes, etc., have fallen on the inside of the wire. The wire rolls will, of course, have been cleaned and washed before being put in, but the hose-pipe should be freely used again. A very wise precaution is to start the machine slowly and run the wire round a few turns to allow it to straighten itself out, all watching carefully for any defect or damage.

No attempt should be made to straighten the seam if it is out of square with the edge of the wire. A slight slope is an inherent feature in some forms of twill-woven wires and causes no trouble or difficulties in running.

If there is a top couch roll which has the effect of tightening the wire, the stretch roll has to be freed to keep no more tension than its own weight until the machineman finally tensions it.

The following describes in detail the procedure for changing a wire on a run-out wire part. It will be assumed that the old wire has already been taken off, and the necessary cleaning and washing-down completed.

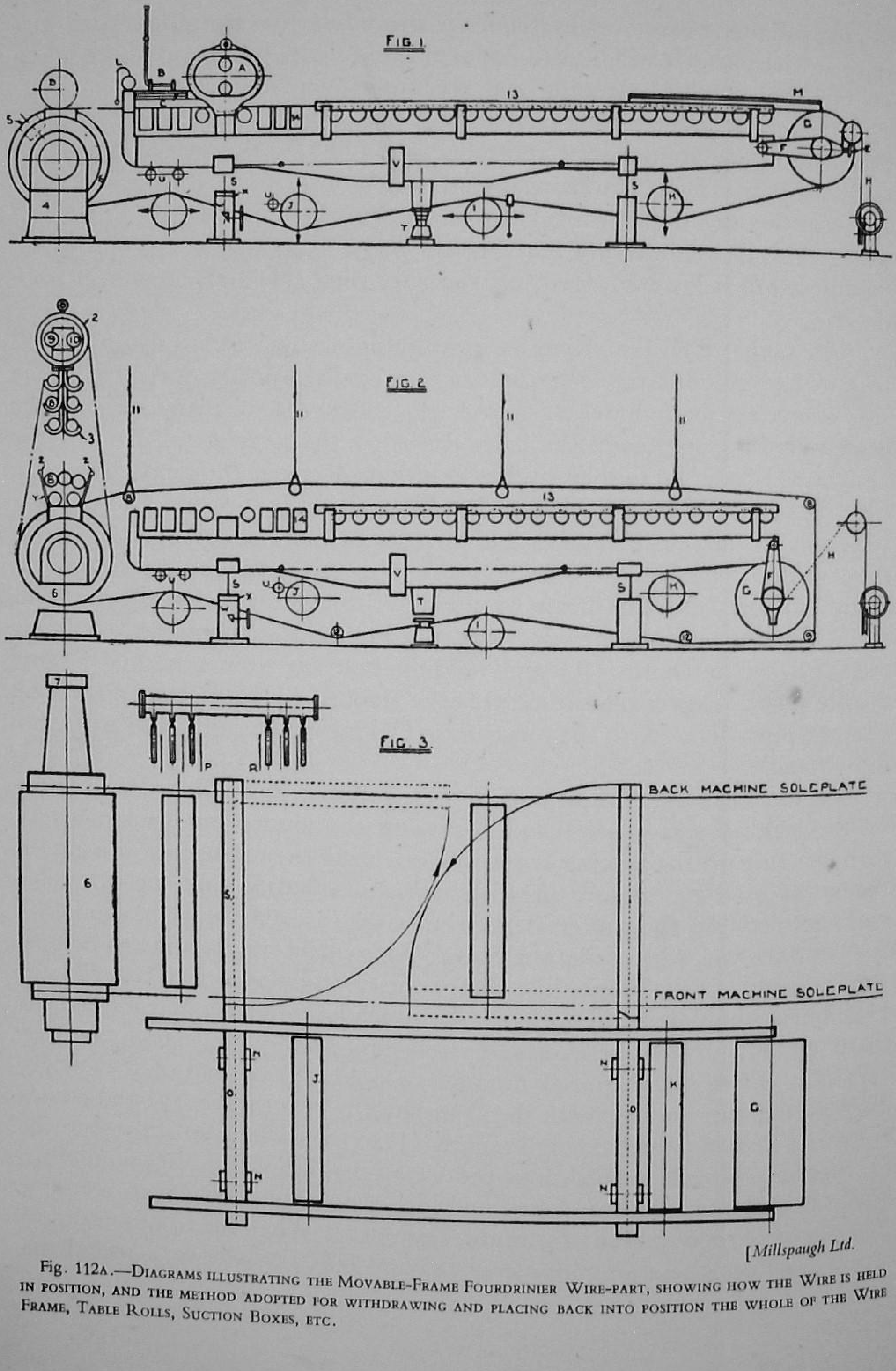
Preparation of Wire Part for Running Out (Figs. 112a, 121 and 122).—Breast Roll (G). Remove the centralizing pin (E) for the arm, and wind up so that the arm (F) comes up against the bronze sleeve on the roll end. Unfasten the cap nuts, swing clear and lower the cap into the breast roll stand. With handwheel on the reduction gears, lower the breast roll. When the breast roll is lowered, slack off the wire rope (H) and disconnect from the arm.

Wire Guide Roll (I). Remove dowel pins or set screws. Lift up the roll back and front, slide the front mechanism forward on the special soleplate and remove the back bracket. Lower the roll to the soleplates, placing the bearing housing spigots in the holes drilled in the soleplates. Wind up the stretchers (J) and (K) to their highest position. Remove the spray cutter (L), edge cutters and Wentz deckles (M). Place the aisle supports (N) on their respective soleplates. It is advisable to letter or number these stands so that they are always used in the same position. Now place the run-out beams (O) on the supports (N) and locate by the dowel pins provided at the machine.

At the back side of the wire part, uncouple the vacuum box oscillating rods (P), suction hoses (R) and holding bolts at runner beams (S) and middle stand. Lower off the centre jack stands (T) until clear, disconnect all spray pipes (U). With the mechanism (V) provided, run the wire part out into the aisle.

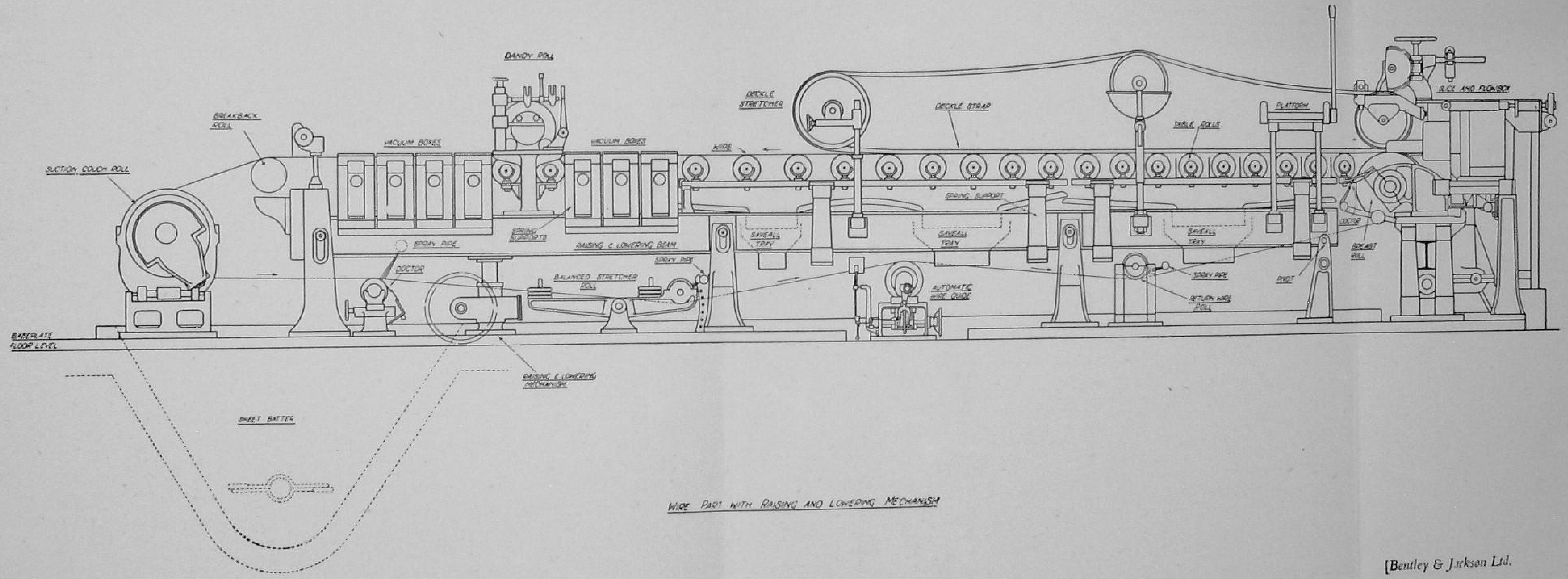
The cross beams (S) must now be swung clear. This is done by screwing up the jacking screws (W) and removing the aluminium packings (X), then lowering off the jacking screws (W) to bring the beams free. Swing the beams (S) so that they are parallel with the soleplates and place wooden packings between the underside of the beam (S) and the jack stand (T). Screw up the jack (T) so that the beams (S) are held rigidly and can be used as a walkway on the front side. Place the wrought iron brackets (Y) for holding the aluminium tubes (8) on the couch housing (taking care that the sharp corners of the brackets are well protected with smooth wooden caps (Z). Place the required number of poles (8) on top of the couch. Pick up the wire bundle with the crane by the two sheaves (2) and secure the wrought iron pole carrying brackets (3) to the under side of the sheaves.

Slacken off and swing clear the swing bolts holding the aluminium stool (4) under the suction couch and lock the suction box (5) in position. The couch (6) is now ready for cantilevering (7). When the front housing is clear, draw out the aluminium stool (4) and feed the wire loop round the



[Millspaugh Ltd.

Fig. 112A.—Diagrams illustrating the Movable-Frame Fourdrinier Wire-part, showing how the Wire is held in position, and the method adopted for withdrawing and placing back into position the whole of the Wire Frame, Table Rolls, Suction Boxes, etc.



[Bentley & Jackson Ltd.

FIG. 112.—WIRE PART OF A FOURDRINIER MACHINE

[To face page 258

couch roll and make secure. Pick up the aluminium tubes (8) and place them in the carrying brackets (3). Now travel the wire bundle towards the breast roll, rotating the sheaves (2) to feed out the wire. As the approximate wire positions are approached, take out a pole and support it across the swivelled beams (S) in a wooden 'U' block to prevent rolling.

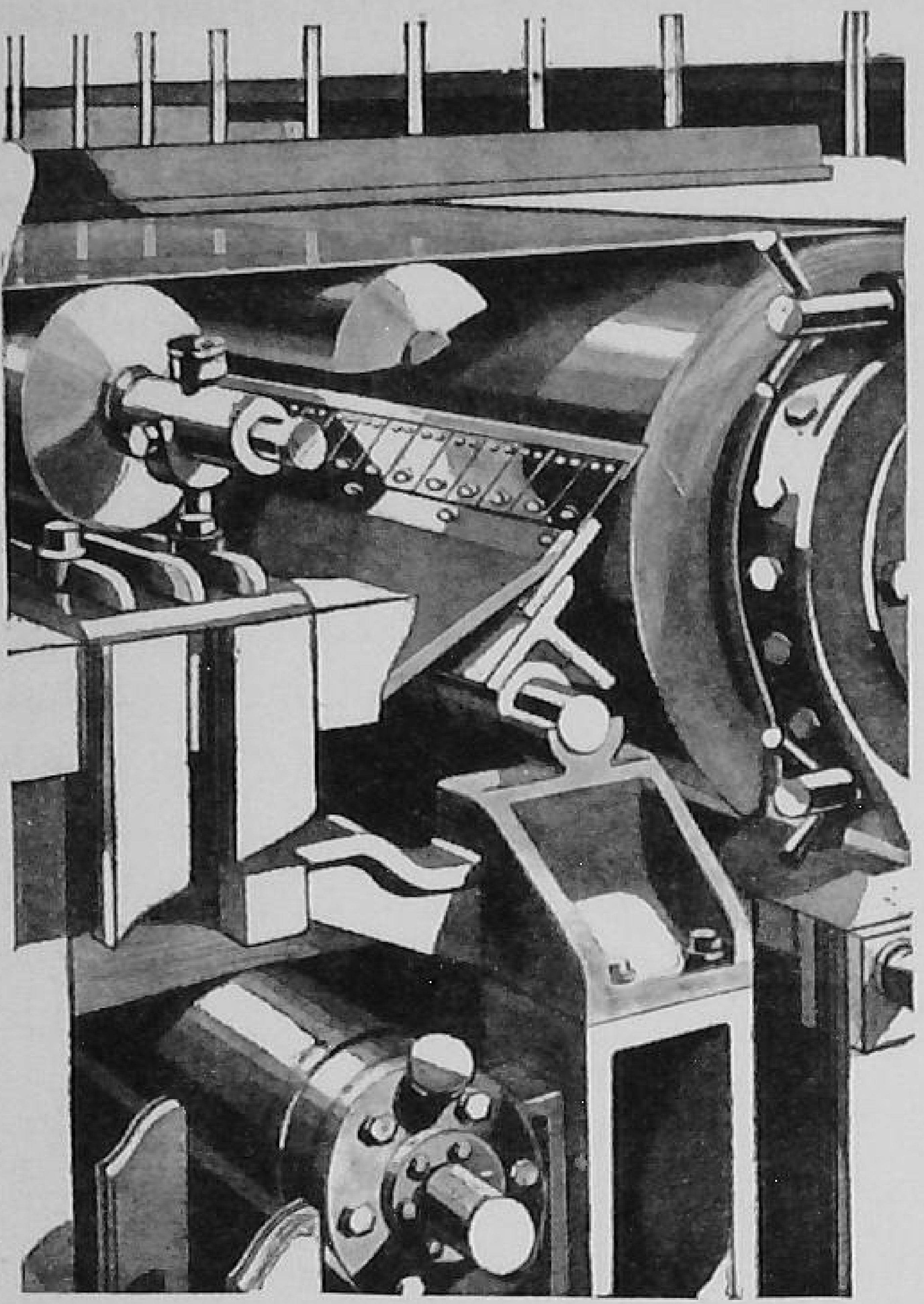
Arriving at the breast roll, support the last inside wire pole (9) (bundle) by rope sling from the crane hooks. Slacken off the jaws of the sheaves and remove the outside pole (10) up on to the slice platform by hand. Now remove the sheaves (2) from the crane hooks and place the inside pole (9) into the brackets at the breast roll stands. Drive the crane clear and lower the rope slings (11). Lift the aluminium poles (8) into the slings and hoist the wire up to give the most slack on the under side. Now place in the lower poles (12) and hoist up the wire until it is high enough to allow the shake rails (13) to pass inside. Replace the swing beams (3) and aluminium packings (X). Run the complete wire part back inside the wire, and make fast all the holding bolts on the back side. Lower the wire and poles (8) on to the shake rails (13) and run the slings (11) back into the roof. Remove the poles (12 and 9) from the under side of the wire part, and also those above except the one at the breast roll. The poles (8) above the wire part will be most safely and easily removed along a vacuum box top (14).

Bring up the breast roll (G) into position, using the remaining pole (8) to keep the wire clear of the breast roll doctor blade. If a forming box is used great care must be taken that the wire does not bend sharply over the edge of the top, otherwise a kink will occur; this again is done by movement of the last pole (8). Take care also that the wire is not creased against the slice bottom lip plate. Replace the remaining parts and remake connexions in precisely the reverse order to that in which they were removed. Remove extension beams and supports, and wire poles, sheaves, etc.

Care of the Wire.—It is necessary at all times to keep a close watch on the wire, and more especially when starting up. The wash roll under the wire, which is cleaned by a doctor board, does not always start if the wire is not very tight, and this may be the cause of stuff getting on to the next roll and making a ridge in the wire. A very sharp spray of water is essential here; it should strike the wire from the inside and impinge on the roll itself, or, better still, two sprays are more effective, one spraying through the wire a few inches before it reaches the wash roll, and the other after it passes the roll and impinging on the roll at the contact point of the doctor board.

The breast roll (Fig. 113) also is a source of danger if the doctor board is not true all across, since a very small piece of pulp or foreign substance may

pass, or even a layer of scale form, from the water getting through. Water passing the doctor at a part where the latter fits badly will cause a ridge in the wire, if the speed of the roll is high enough to carry the water round and under the wire. Where wood pulp is used a very stiff and close-fitting doctor board is required to scrape off sulphite pitch.



[*Vickerys Ltd.*

FIG. 113.—THE BREAST ROLL FITTED WITH VICKERY DOCTOR

Before he starts the wire, the machineman ought to have a good hose-pipe handy, with the water turned full on, ready to wash off the wire rolls as soon as the paper is on the felt. If the stuff should run up the top couch roll, this hose-pipe may be immediately used to wash it down the wire. In this case, if any stuff has got jammed in the nip of the guard board, when the board is lifted to free it the piece must be caught before it drops down on the wire. It is the practice in some mills to use a 'starting sheet'. This is laid on the stuff as it reaches the suction boxes and may be easily caught coming through the couch rolls, and serves to lead the wet sheet on to the felt. If the machine is started with the dandy roll running on the wire, this introduces an *unnecessary* element of risk, since the stuff is seldom correct for taking a water-mark when it first reaches the first suction box.

Bits will be picked up by the roll, and may attain some thickness, layer by layer, before they can be got off, generally to fall on the wire and go through the couch rolls. Or it may happen that the stuff is more wet or more free than the machineman has calculated on, or he may have too much or too little stuff or water. The presence of the dandy roll then adds immensely to his difficulties. If the roll is not down, the suction boxes have a far greater chance of taking water out of the sheet. When the machineman has got his stuff and water suitably proportioned and his level approximately correct, he may lower his dandy roll on to the paper with confidence. On moving the ends of the suction boxes, or when packing them with stuff, bits may be

carried round and on to the wire rolls. An accident that is not uncommon happens when a piece of some foreign substance, such as a small stone, piece of cement or sandy particle, is washed into the wire by the indiscreet use of the hose-pipe on the floor in front of the wire.

The hose-pipe, when washing up the floor, must always be directed to send the jet *away* from the wire.

An uncovered strap or pulley may fling a piece of fibre, or even a belt fastener or rivet, into the wire, or on to the table. A machineman should be careful to have all the buttons on his clothing firmly sewn on and to remove his collar studs when he takes charge. Any one of these may fall or jerk on to the wire when he leans over the slices or other adjustments. When putting on or repairing connecting strips or aprons, all tacks, screws, pieces of rubber, etc., and all tools should be picked up and accounted for before moving the wire again. When removing stringy fibres from the slices, no hard, pointed instrument may be employed. The best method is to run the tip of the finger along the edge.

No spanners, broke, etc., should be thrown down near the wire, and the space both at back and front should be kept clean and as clear of all machine-house fittings as possible. Shake must be stopped as soon as paper is off the wire.

When the machine is shut for the week-end, sufficient sprays to keep the wire wet should be left on. Some managers insist that all water be shut off in the machine room, but when this is done suction boxes, couch-roll covers, apron and connecting straps dry up and get spoiled by shrinkage, etc., with loss of time and bad work when starting up again. But unless every part of the wire is kept wet, or if a draught dries up a space, a 'tide mark' will be formed which is very difficult to clean. A very old custom is to leave the wire seam over the week-end in the nip of the couch rolls, 'to keep it flat', but it is obvious that it can do no good, but only harm, for the seam to be under heavy pressure for any length of time. The best place to leave the seam is on the breast roll.

The second set of factors which influence the life of the wire are, generally speaking, constant and unavoidable, though some may be minimized if proper precautions are taken. One of the worst enemies of the wire is the necessity of using hard water, which forms deposits of calcium carbonate. The latter, however, and the general clogging up of the mesh of the wire by loading, size, etc., are to a very great extent preventable and depend on several things, which will be touched on later.

As far as the machineman is concerned, it will be found that if he adjusts his back-water system carefully he will use the same water over and over

again, with very little addition of fresh water, which causes the deposits. Except where special treatment of white-water is carried out, fresh water must of necessity be used in the sprays of the wire rolls, so that after a period the wire clogs up and must be cleaned. A steam force jet, judiciously used—say once a week—will help to lengthen this period, but there are now special cleaning agents on the market which clean the wires with less damage than sulphuric acid.

Hydrochloric acid may be used to clean the wire of limy deposits. A 50 per cent solution from an earthenware or glass bottle should be applied to the top of the wire with an old scrubbing brush, and washed out with the force jet before the solution reaches the couch roll.

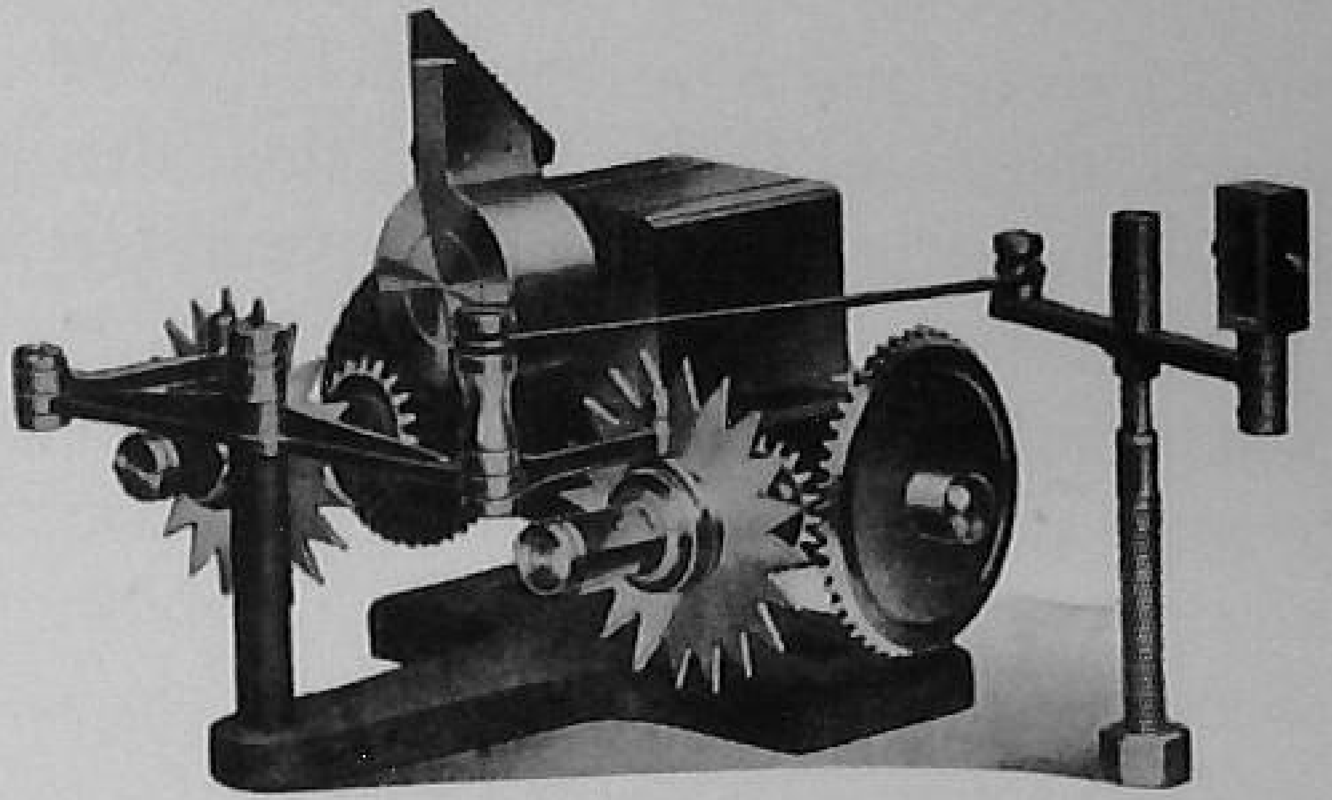
Then there is the wear of the wire by the rolls and tops of the suction boxes. As far as the rolls are concerned, they should be kept well lubricated, and especially the tube rolls which form the table. Also, any side play on their spindles or brasses must be watched for, as in this case the action of the shake will make the wear much greater. The weight of the breast roll is important. Very often it is made too heavy, thus imposing an unnecessary strain on the wire in pulling it round, and more so when starting up. Deckle straps, where there are many changes of sorts, make the wire dirty and cause more or less ridging; so also do the movable ends of the suction boxes, owing to there being a pull over their inner edges. The shake has a twisting action on the wire just before it is held by the suction boxes. Dandy rolls that are too short and have prominent discs on their ends are a source of trouble. Cracks on the edges of the wire are often caused by the 'spades' of the guide roll stick.

Setting and Running the Wire.—After a new wire has been put on, and all fittings have been replaced, it is necessary to tension and 'set' the wire, so that it will answer to the guide (Figs. 114 and 115), keep in the centre of the machine and make an equally couched and uniform sheet. With the stretch roll swinging freely and the top couch roll with equal weight on both sides, the new wire should run for a few minutes and be worked by hand guidance to the centre of the rolls. The guide-bar spades are then fixed close to the edges of the wire. There is no need to leave any space for the wire to move, unless it has an irregular or a waved edge, when sufficient is left to keep the edges from being rubbed and frayed. A few more turns will show whether the guide roll is set so as to be able to keep the wire in position.

There are several ways of guiding the wire with mechanical aids, and generally speaking wire guides are very unsatisfactory pieces of equipment. The older types, which were probably quite satisfactory for running at slow speeds, have not been improved upon very much, and some of the

newer mechanical types give a lot of trouble due to faulty design, failure of bearings and unsuitable metals; and these frequently cause the loss of a wire.

The principle of the wire guide is as follows: usually two 'spades' or upright pieces of sheet metal are fixed to a rod which passes under the wire, and these so-called spades are so placed that they almost touch the edge of the running wire, front and back. If the wire moves to the front it contacts the spade and pushes it away, and this causes a pawl, which is being operated by the guide roll, to engage on the serrations of a wheel mounted on a screw which carries the bearing of the guide roll. As the serrated wheel is made to revolve by the repeated impact of the pawl, it causes the guide roll to be moved at one end, forward or backward, along the screw, and this alters the alignment of the guide roll across the machine, thus causing the wire to go back or come forward according to which spade is being pushed by the moving wire. The travel of the guide roll is so arranged that it will generally stop the movement of the wire in time, and bring it back to its central position.

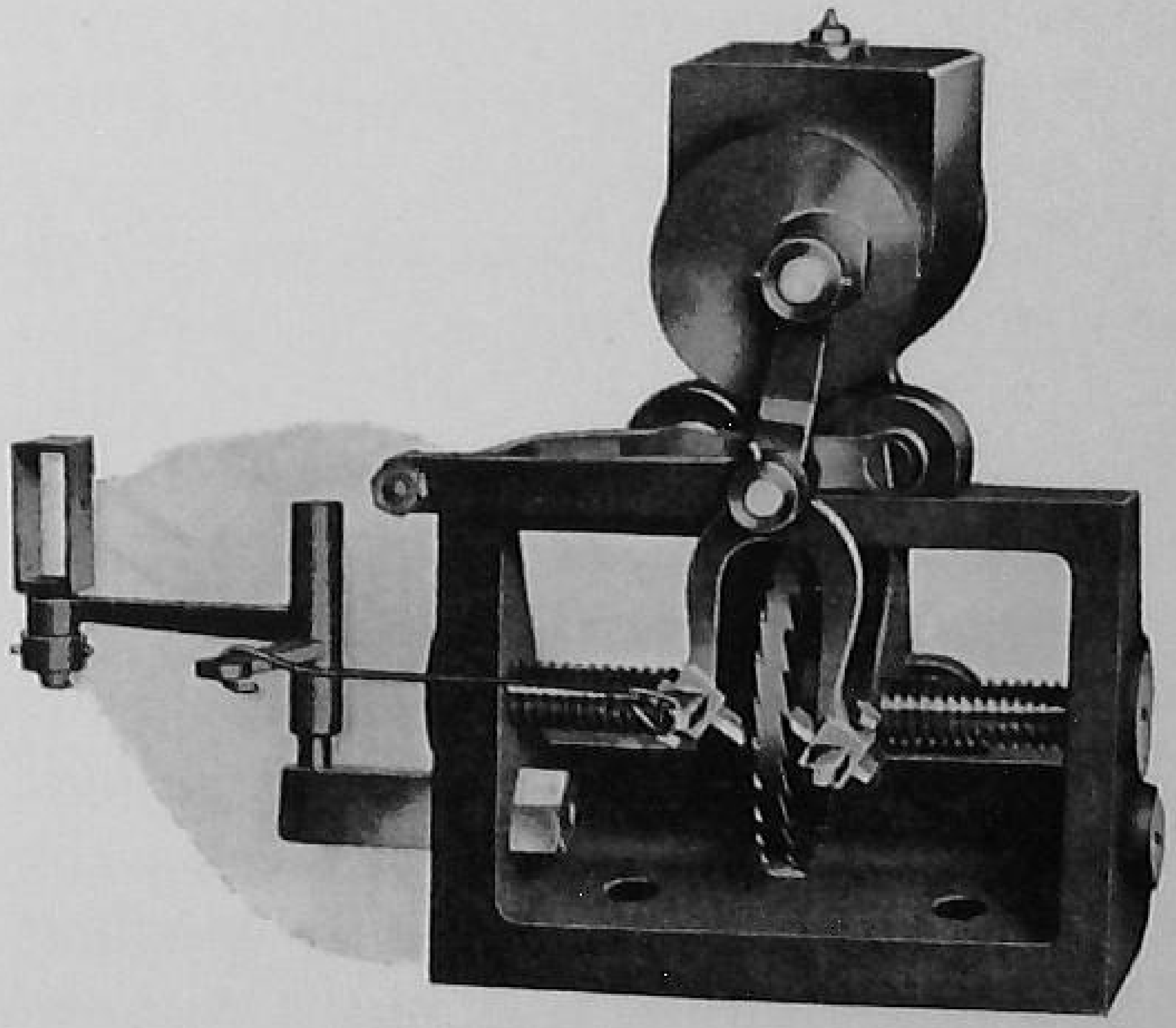


[*James Bertram & Sons Ltd.*

FIG. 114.—AUTOMATIC WIRE GUIDE

Attempts have been made to guide the wire electrically by means of an electric eye, but these have been generally very troublesome owing to the difficulty of keeping water away from the electrical equipment.

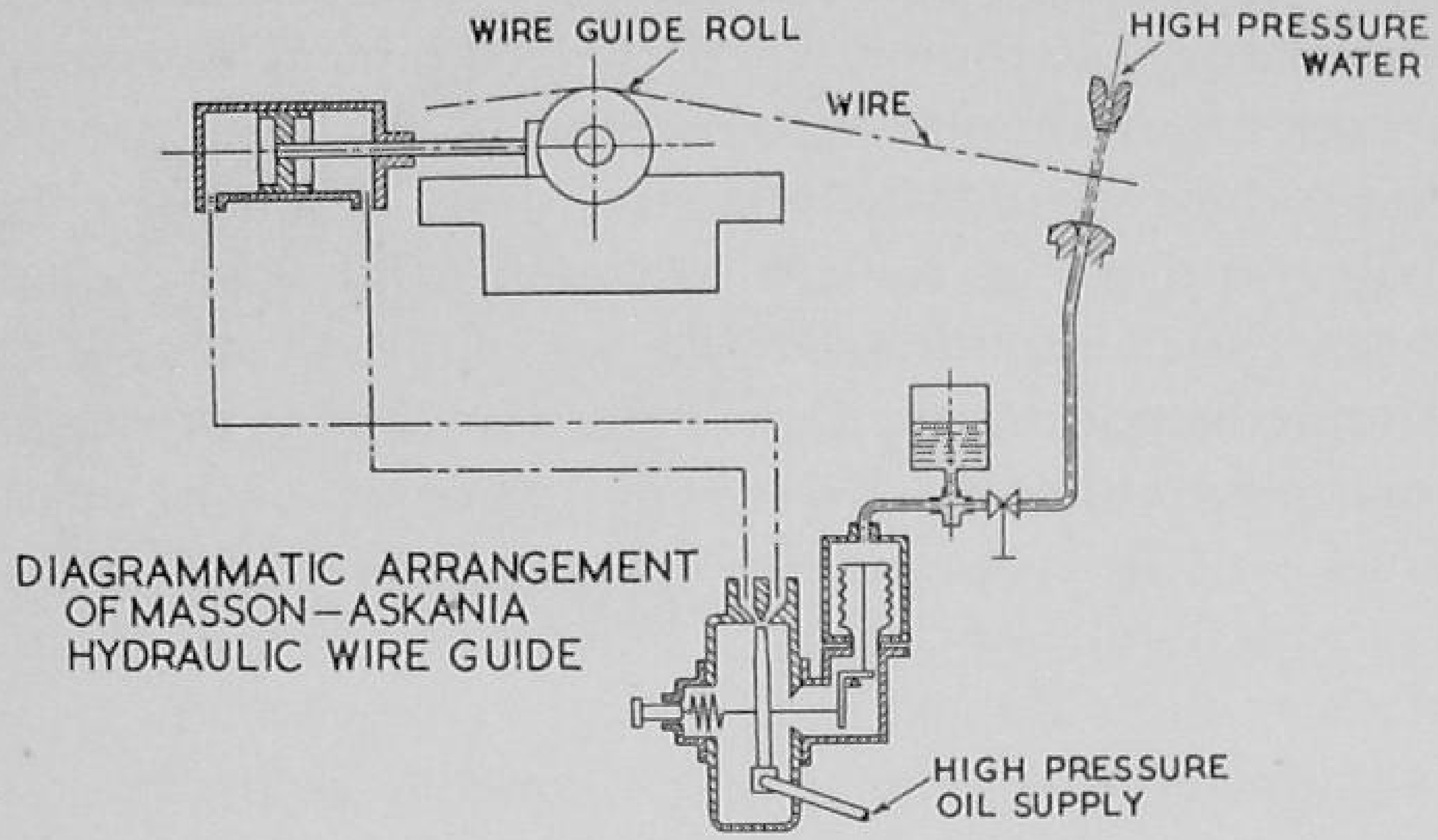
On most paper-machines the guide roll is situated between the last suction box and the couch, and in this case the wire slopes down from the suction box to the couch, so that the guide roll has a fair amount of wire overlapping it, and it thus has sufficient control over the wire to cause it to move if the guide roll is put out of line. On other paper-machines the guide roll is arranged on the return of the wire, about the middle of the



[*James Bertram & Sons Ltd.*

FIG. 115.—AUTOMATIC WIRE GUIDE

wire frame after the wire has passed the stretch roll, and is on its way back to the breast roll. Although this arrangement appears to work quite



[*Masson Scott & Co. Ltd.*

FIG. 116.—DIAGRAMMATIC ARRANGEMENT OF MASSON-ASKANIA HYDRAULIC WIRE GUIDE

satisfactorily on some machines, it cannot be said to be universally acceptable. One reason for this would appear to be that the wire is often slacker on the return than on the top side, and in consequence the putting of a guide roll out of alignment does not appear to have such a quick action in causing the wire to come under the control of the guide roll. The actual run of the wire between the two points on either side of the guide roll also seems to have some influence on the behaviour of the guiding arrangements. In this case the two points would probably be the stretch roll and a supporting roll either inside or outside the wire between the guide and the breast roll. The Masson hydraulic wire guide is being used with great success on some paper-machines in this position, and it seems that it may be the answer to a lot of the troubles which have been experienced in the past from mechanical guides.

Masson-Reavell-Askania Wire Guide Control. The application of the Masson-Reavell-Askania Regulator to wire guide control on paper-making machines is as follows:

Referring to Fig. 116, the jet pipe and cup device located on one side of the wire is so arranged that the water jet intercepts the edge of the wire and the degree of interception dictates the impulse pressure recovered in the cup. This pressure is taken to the bellows of the regulator impulse system and any variations are transmitted via push-rod, bell-crank and push-rod to the jet pipe of the regulator where they are balanced against the force in spring,

variable by means of the adjustment. An air vessel and throttle valve are provided immediately before the bellows impulse system.

High pressure oil flowing through jet pipe strikes midway between orifices of the regulator distributor when the jet pipe is in mid-position, corresponding to the mean impulse pressure; that is, the mean position of the wire screen. Under these conditions pressures in oil connexions to control cylinder are equal, and piston stationary. As soon as the wire commences to move from its mean path a greater or less degree of interception of the water jet produces pressure variation in the impulse pipe. This is transmitted as described to the jet pipe which is deflected to right or left as the case may be. Pressure rises in one of the connexions and piston of cylinder moves the skewing mechanism of the guide roll to correct the deviation which has taken place.

Permanent hunting having a cycle of 5 seconds is set up due to:

(*a*) the idle travel of the control cylinder spindle;

(*b*) the limits imposed on the piston stroke by the maximum roll movement;

(*c*) the lag on the impulse line.

A secondary sideways oscillation of the wire having a time cycle of 5 minutes and a magnitude of up to 1 inch sideways movement of the wire is set up by a special mechanism fitted by the makers to the jet and cup portion of the apparatus. The oscillation of this jet, the axis of which is coincident with the centre of the cup orifice, will result in what amounts to a resetting of the regulator impulse system and variation over a 5-minute period of the mid-position of piston of control cylinder.

The system, as described above, will function, if necessary, without the secondary 5-minute sideways oscillation provided the water jet is locked in position.

The stretch roll may now be put down a little if it is light and experience shows that it is necessary. A heavy roll will not require to be put down, but its spindles should have enough pressure to keep it from jumping. On starting again, if the seam is fairly straight and the tension from the boxes to the couch rolls is equal on both sides, it may be assumed that the wire is correct for a start-up with paper.

There is, however, a very great difference in the running of a wire without stuff and with stuff. In the latter case the suction boxes hold the wire, and the couch rolls have to pull it across them, thus creating a tension which is very much greater at this point than anywhere else. Therefore the top coucher has the most important influence on the wire. The slightest difference in the pressure applied alters the tension between the boxes and the nip.

This may possibly be so much that the wire is extremely tight at one side and so slack at the other that it is impossible to keep it in the centre of the machine, the guide roll being unable to send it back to its place.

Then the tension of the stretch roll will be found to be greatest on that side where the tension from the boxes to the nip is least. It is here that a machineman may make a mistake by altering the stretch roll in an attempt to straighten the wire. Instead, weight must be taken off the couch roll on the side which is slack, between the boxes and the couch roll, until both sides have the same tension. Then the seam should be carefully watched, and if any alteration is necessary, the stretch roll may be put down on the side which is leading. The alteration may change the tension at the nip a little, and both sides of the wire must be carefully watched until the tension remains the same and the seam is straight. It will then be found that the wire will keep well in position and be guided by the ordinary automatic movement of the guide roll.

If the stretch roll is not quite level, this is immaterial so long as the seam is straight and the tension is correct, since some wires appear to have a slack side. This is very difficult to decide, because it is possible for this appearance to be caused by the inclination of the couch rolls or wear in any of the brasses of the wire or breast rolls. For this reason it is very much worth while for the engineers to test these things when the wire is being renewed. In particular, the back side brasses of the bottom couch roll tend to have more wear owing to the pull of the clutch, and perhaps to having less attention paid to them in regard to cleaning and oiling. When this happens the back shaft and the couch rolls are not in alignment, and the result is an eccentric action in the clutch which causes a rise and fall of the couchers.

It often happens that a wire will travel slowly to one side of the machine and cling there, in spite of the guide roll being fully set to bring it into its place. This is more inclined to be at the back side than the fore side, because the guide roll has to turn on the back side as a pivot, and therefore has less control of the wire at that side. There is very great danger in this situation, and a machineman has to be very much on the alert lest the wire turn suddenly and come over too quickly, doubling up its edges on the guide-bar spades. But assuming that no further alteration of the guide roll is possible, and the wire shows an inclination to go too far, then the suction may be partly shut off the last box, or the air valve opened a little. Then the wire will return to its place with a run, which can be quickly checked by again putting on the full suction and squaring up the guide roll. This will seldom take place if the tension from the boxes to the nip is properly adjusted, but it must be clearly understood that the coucher must not be used to control the wire.

It may happen that a wire will run very well with the sides at the nip not equally tight, so long as the paper and suction are on it; but couching will be unequal, because the tight side has the least weight on it. In this case, if the machine is shutting down and the wire runs empty for a few turns, the heavier-weighted side may slacken so much more as to run through the nip in wrinkles, when the wire is rendered entirely useless.

For this reason it is very inadvisable to run the wire empty for more than a turn or two to clean it off, unless the machineman is very sure that his coucher weights are perfectly adjusted.

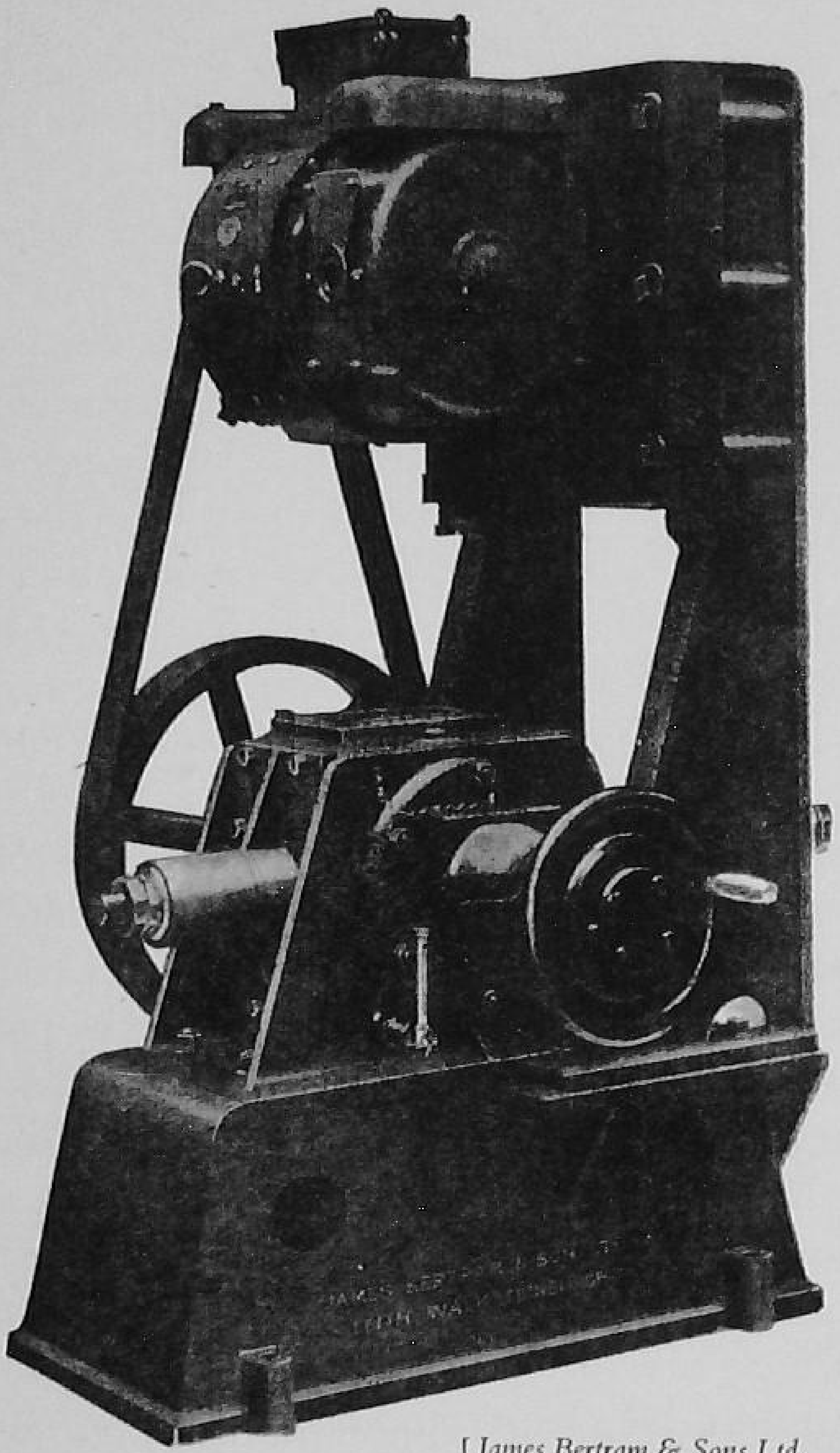
The level of the guide roll to the last suction box has a very important bearing on the steady and trustworthy guiding of the wire. If the guide roll is too low, the suction box will control the wire in spite of the roll. This is shown by a wire running to one side and coming back with a dangerous run when the suction is eased off. The guide roll may work very far forward to send the wire back, or vice versa, and this introduces another complication which makes matters worse. The roll being too far advanced—say at the front side—and the wire tending to come to that side, the wire is thereby tightened up between the box and the coucher. This in itself ensures the tendency of the wire to come forward, since a wire will always run towards the side on which the wire is tightest, between the box and the couch roll. The guide roll should in all cases be just so much under the level of the last suction box as not to interfere with the suction; $\frac{1}{16}$ inch is quite sufficient. Most of the machineman's uncertainty as to the guiding of his wire will be eliminated if this vital point is attended to.

The Tube Rolls.—The tube rolls have two functions: first, they support the wire from the breast roll to the suction boxes, and form a table with the wire on which the stuff and water are evenly spread and formed into paper. For this purpose they must be accurately levelled from side to side and to each other, and at every renewal of the wire, examined and thoroughly cleaned. Great care should be taken in replacing them in their proper order. They are usually numbered for convenience. A safe place should be selected for them to lie until they are put back.

Although paper-machines will run satisfactorily and make good paper with stationary tube rolls, it is usual to have these rolls fitted with very free-running bearings. If the bearings are ordinary brass, they should be kept well and regularly greased or oiled. Ball bearings are now available which will withstand the conditions and keep out water, and they are in every case to be recommended.

It is important that the tube rolls should be of a sufficient diameter to enable the usual speed to be run, without the throwing of water from the

rolls. In some cases it is necessary to put doctors on the tube rolls, or baffle plates, to catch the water thrown off by the roll and prevent it being taken up to the wire again.



[*James Bertram & Sons Ltd.*

FIG. 117.—SHAKE MOTION, WITH VARIABLE SPEED MOTOR FOR SPEED ALTERATION

The stroke is altered by the hand wheel

Their second function is to draw water from the sheet. A layer of water forms on the under side of the wire, a tube roll rubs or drains it away, leaving a partial vacuum in each minute pore of the wire. This immediately fills with water and is emptied by the next roll. Thus it will be seen that the number of tube rolls has a definite relation to the length of the wire.

A short wire, closely tubed, can deal with wet stuff, as far as extraction of water is concerned, nearly, if not quite, as well as a longer wire with the same number of tube rolls.

The Shake.—For the purpose of closing up the fibres into a compact sheet, it is necessary to impart a sideways shake to the wire frame. This is accomplished through the medium of a shake motion, which is a machine operated by a variable speed motor, and containing an eccentric running in an oil bath which is connected, through a shaft, to the wire frame at the breast roll. There are a number of excellent shake motions available to paper-makers at the present time, notably one made by Messrs. James Bertram & Sons Ltd., and also the 'Westbury' shake motion, both of which are illustrated (Figs. 117 and 118).

These shake motions enable not only the length of the stroke of the shake to be varied at will while the machine is running, but also the speed of the shake. Whereas a comparatively few years ago shakes of only $\frac{1}{8}$ to $\frac{1}{16}$ inch in length of throw were in general use, nowadays it is quite

common to shake the wire frame as much as ½ inch, or even ⅝, and to have the speed of the shake as high as 350 or 400 shakes per minute. In order to

[*Westbury Engineering Co. Ltd.*

FIG. 118.—SHAKE MOTION WITH ADJUSTABLE SPEED AND LENGTH OF SHAKE

accomplish this on modern machines, the frame is supported, or hung, on flexible steel, or micarta hinges or springs, so that the action becomes a soft swing, compared with the hard jerk on the old types of shake motion.

The slope of the wire from the breast roll to the suction boxes depends largely on the speed of the machine, and also in some degree on the quality of the paper being made, and the freeness, or wetness, of the stock. On large machines, such as those making newsprint, and running at high speeds, the wire frame is usually sloped quite a considerable amount from the breast roll to the couch or suction boxes. In some cases, the slope may be as much as 18 inches, with a wire 100 feet long. On the other hand, very slow running machines, making strong, thick papers from rags, and with much shorter wires, may need a slope upwards from the breast roll to the suction boxes, but

in this case the slope is usually much less, and may probably be about 2 inches.

Many machines have equipment which enables the slope of the wire to be altered at will, and this will be found a great advantage when varying qualities of paper have to be made on the same machine.

On a number of machines nowadays a forming board is fitted immediately after the breast roll and before the first tube roll. This board is about 12 inches wide across the width of the wire, and the object of it is to retain water in the web while the shake motion is having an effect on the stuff on the wire. It is claimed for these forming boards that they assist in the better formation of the sheet, although they cannot be said to have been a complete success in every case.

Another idea incorporated in some machines, and designed to have the same effect as the forming board, is a dandy-type of tube roll. There may be one or more of these taking the place of the first one or two tube rolls after the breast roll. It is claimed for these that they help in controlling the removal of water, and give a better appearance to the sheet. Where it is desired actually to retain water in the web for a fair distance down the wire, when the stuff is too free, these dandy-type wire-covered rollers give this result.

CHAPTER XVII

THE FOURDRINIER MACHINE (*continued*)

Deckle Straps to Machine Drive

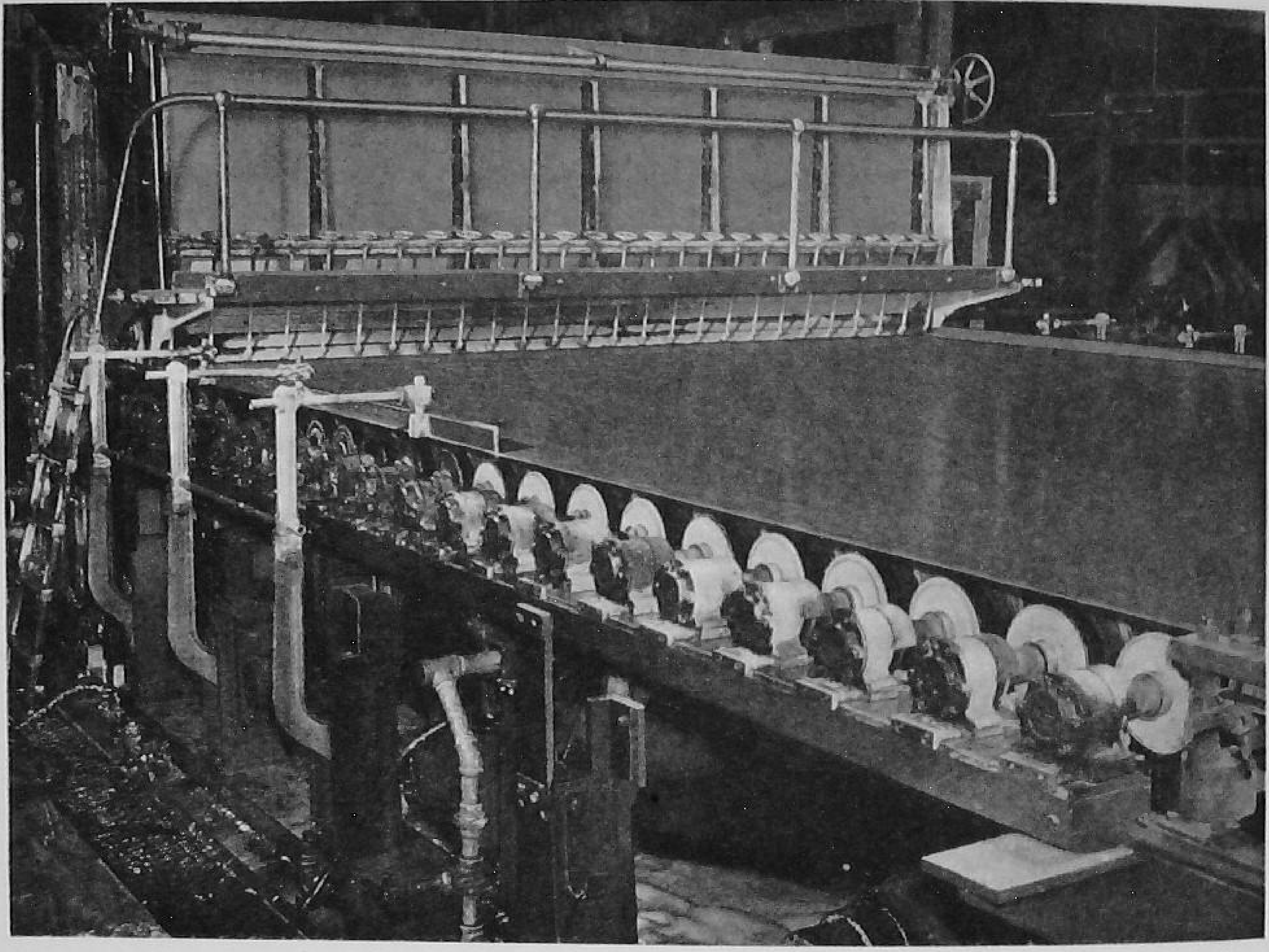
Deckle Straps.—These are the endless rubber bands which keep the stuff on the wire. They are composed of flexible rubber with a core of harder and stronger material to give them stability. They should be of sufficient weight and bulk to prevent the stuff from flowing under or pressing them outwards. They are carried on flanged pulleys, movable outwards or inwards to suit different widths of web. Often deckle straps are far too big and heavy, and they cause a strain on the wire, and frequently damage it. A deckle strap should never be heavier or longer than is absolutely necessary. It is possible on some machines to manage with deckle straps only about 6 or 7 feet between centres, depending on how the stuff parts with its water.

On many machines the deckle strap has been superseded by a fixed deckle, generally known as the Wentz deckle. This consists of two pieces of wood between which is clamped a thin strip of plain rubber. The rubber protrudes about half an inch from the bottom of the two boards, and touches lightly on the wire. The two pieces of board are held in position by brackets from the wire frame, and the length of these has to be found by experiment, in order that wet stuff is prevented from running off the wire on to the floor. It will generally be found that if these deckles are 4 or 5 feet long, for speeds of about 500 feet a minute, the object of keeping the stuff on the wire is achieved, and there is far less risk of damage to the wire than with the older types of deckle straps which run on the wire. There is little or nothing, with these fixed deckles, to injure the wire, and they are very easily adjusted. They are very clearly shown in the illustration, Fig. 119.

A trickle of water must be continually run on the inside of the straps; otherwise they will soon become dry and stick to the pulleys. If this happens a strap may stop, and this often means a ruined wire, owing to hard rolls of pulp going through the couch rolls. Bruises or cracks on the edge next the wire will result in a little 'leaf' being formed on the edge of the paper, with a corresponding thin place behind it.

This may be picked up by the press rolls and cause a break there or at the dry end of the machine. If the edges of the strap are rough, uneven, dirty, or have a hard lump, the same trouble will result. If a strap is too long, the return portion will swing and sag and cause it to move forward on the wire

with a jerky motion. If too short, or with perished and sticky places, it will drag and make rolls of pulp on the deckle edge.



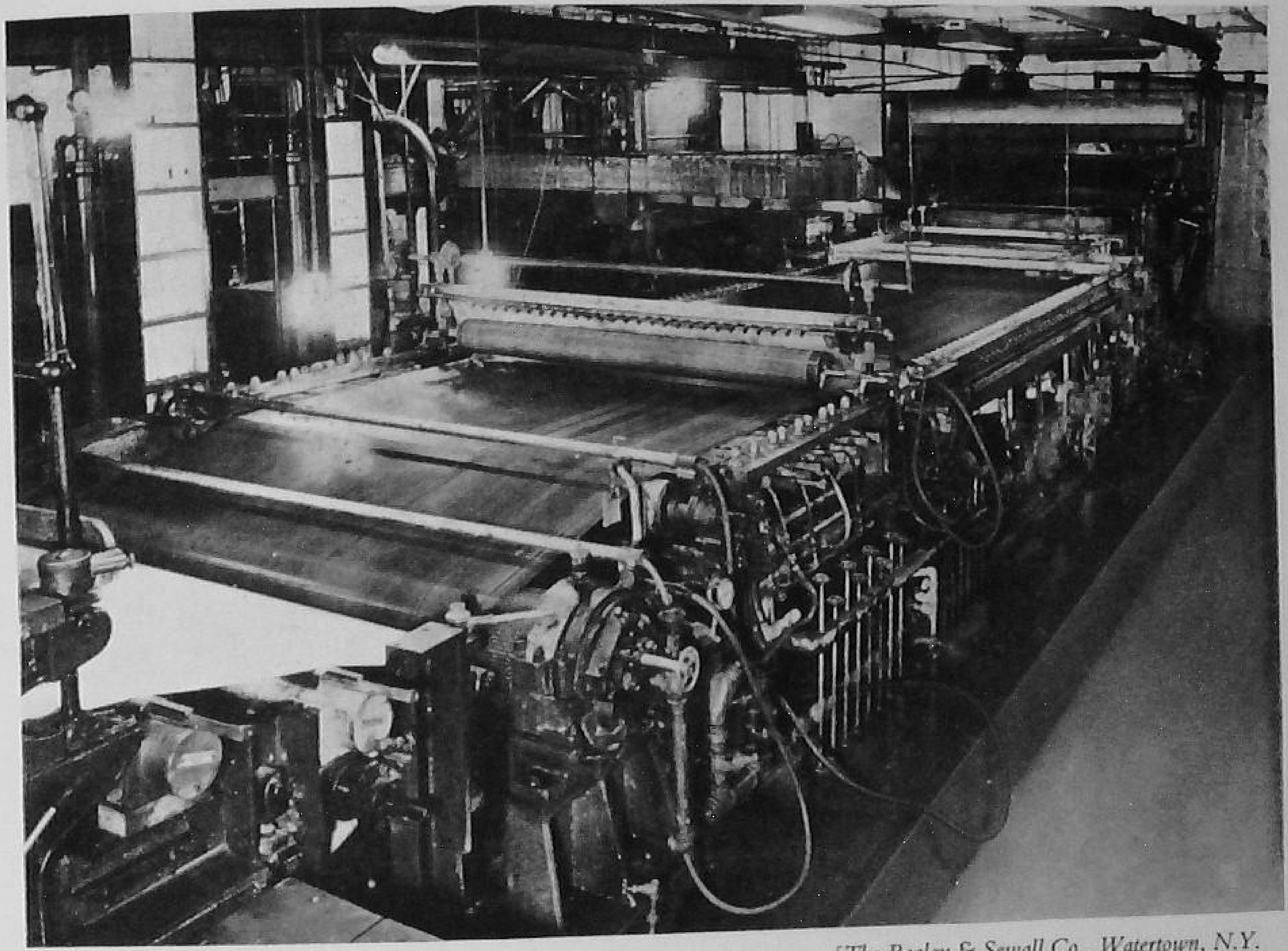
[The Bagley & Sewall Co., Watertown, N.Y.

Fig. 119.—Breast Roll End of Fourdrinier Machine Wet End, showing Projection Slice, Deckles and Tube Roll Bearings

It is important that the side that runs on the wire should be slightly concave, otherwise there will be a continuous bad edge. It often happens that a strap is bruised or otherwise damaged when changing a wire. Therefore, too great care cannot be taken to see that they are skilfully handled, placed where there is no probability of their being made greasy, and well away from the work going on, until they are replaced. If spare straps are kept—and this is a wise precaution—they must be stored in a cool damp place, and kept in such a position that they have not to take any acute bend or twist, as after a time this will become permanent and render them useless.

When changing deckles, the pins holding the deckle pulleys may be slacked off and the pulleys assisted to move in the required direction. If the strap runs off the pulleys, the wire may be scored and the strap damaged.

It must not be forgotten to tighten up the pins again; they may drop out and be carried through the couch rolls, with disastrous results.



[*The Bagley & Sewall Co., Watertown, N.Y.*

FIG. 120.—WET END OF FOURDRINIER MACHINE NOT EQUIPPED FOR QUICK WIRE CHANGE

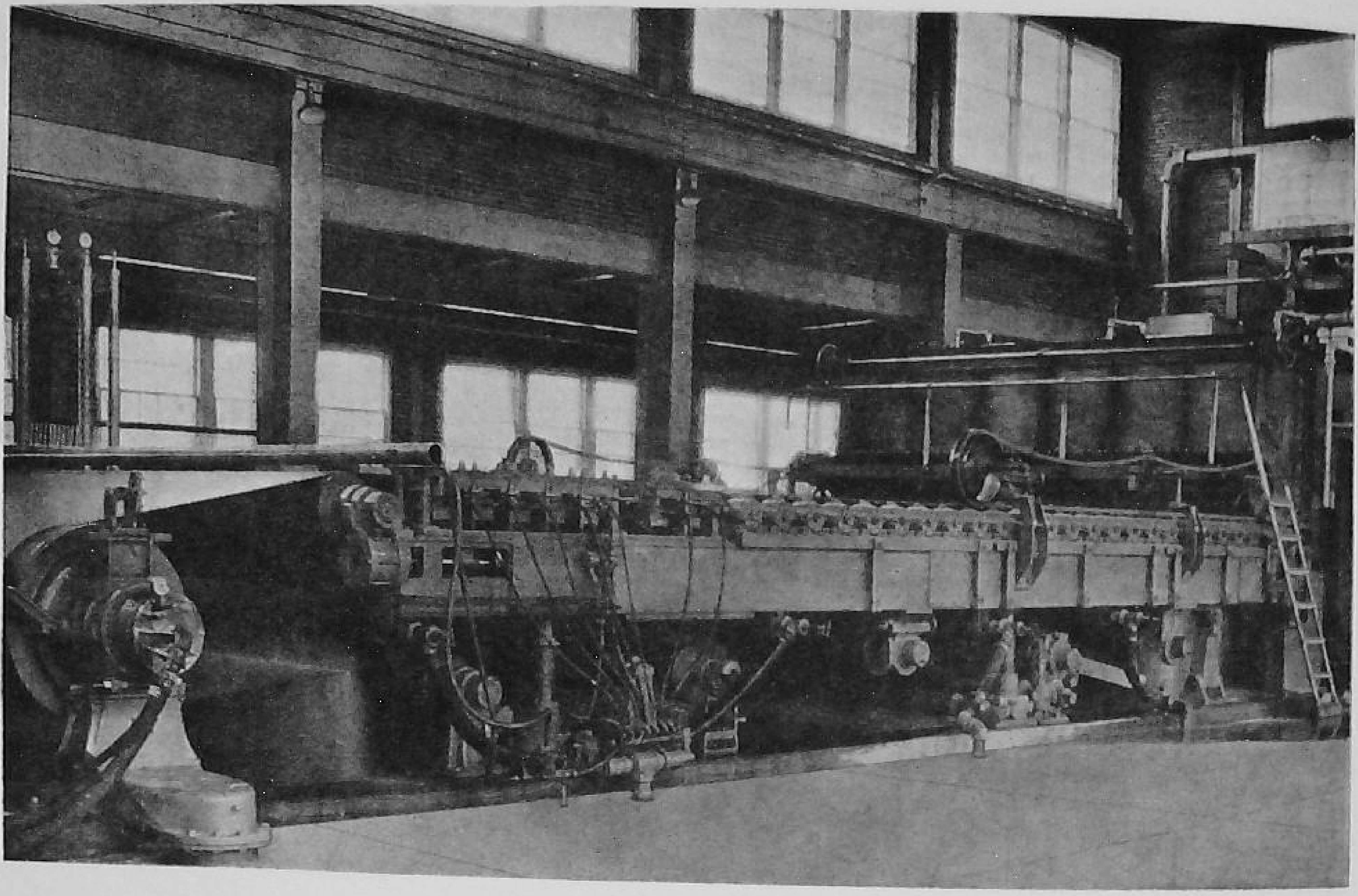
The suction couch, guide roll, suction boxes and dandy roll are clearly shown, also individual suction box control equipment.

The deckle pulleys ought to be oiled and wiped clean at every opportunity. A stiff-running pulley will make the strap jerky and cause a lot of breaks before the source is discovered.

Suction Boxes.—Many machines have only two suction boxes. For making paper from rag stock, when we sometimes get very wet stuff, two boxes are insufficient. In any case, three or more boxes are better than two. Even if the paper we make could be worked with two, it is wiser to have a little suction on each of three or four than a strong suction on two, for then less pressure is put on the wire, which lengthens its period of use.

The usual type consists of an air-tight, oblong box (Fig. 123), very solidly built of some hard, durable wood or brass. It is divided down the centre by an open frame, which supports one or more bars according to its width. The top edges and the bars are covered with very hard wood to take

the wear of the wire. The bars are usually about $1\frac{1}{2}$ inches apart and should not be more, or the wire will be drawn down and over their edges. At the ends



[*The Bagley & Sewall Co., Watertown, N.Y.*

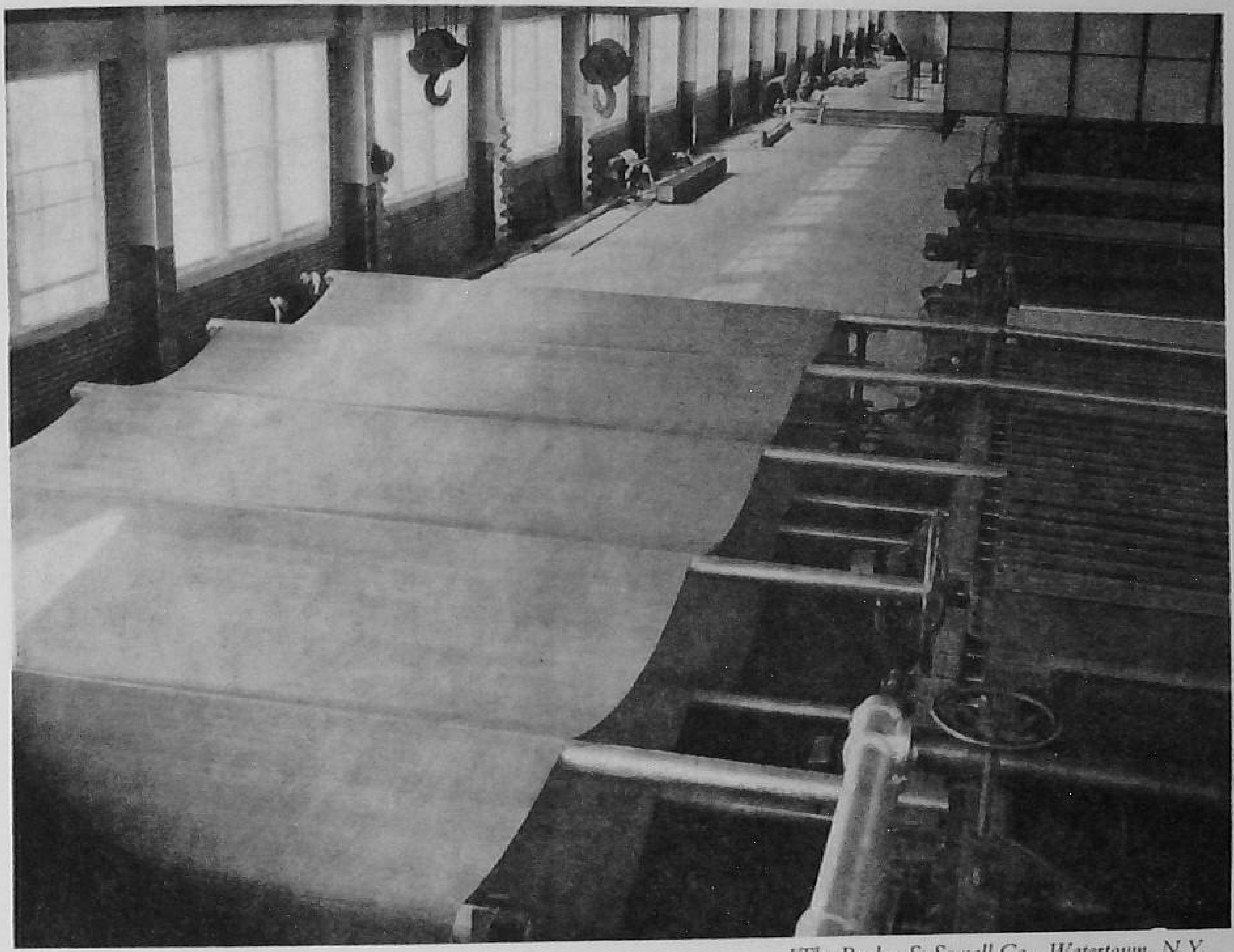
Fig. 121.—Quick Wire Change type Fourdrinier Simplex Wet End

where the edges of the wire travel, brass plates a few inches in length are let in to take the wear of the rough edges. A pipe from the suction pump is connected to the centre of the box at the bottom or the side. Movable ends are provided to enable various widths of deckle to be followed. These are adjusted by a heavy brass screw extending through the outer end of the box. The box is made as rigid as possible, and is bolted and very firmly wedged in place on the frame of the machine. Each box has a valve to regulate the suction admitted by the pipe, and a small pipe comes from the centre of the box to the fore side and is used as a fine adjustment for admitting air to the box. The space between the movable and fixed ends is kept full of water to prevent air leakage, and sometimes the suction may be kept more steady by, in addition, a packing of soft doctor broke.

There is another type of box, used chiefly on 'news' machines, which has one solid board forming the top. This board is drilled with holes or slits *en échelon*, and has movable ends of expanding rubber.

The ideal method of operating suction boxes is to have a separate pump

for each suction box. This is especially the case where other results besides the removal of water are required.



[*The Bagley & Sewall Co., Watertown, N.Y.*

FIG. 122.—QUICK WIRE CHANGING FOURDRINIER, SHOWING WIRE ON SUPPORTS READY TO BE PUT ON TO WIRE TABLE AND TUBE ROLLS

Where a dandy roll is used, it is absolutely essential that there should be a very fine control of the suction box immediately in front of the dandy. This is necessary even with a plain roll when it is important to get a fine, clear-looking sheet, but it is more important still when water-mark designs have to be put into the paper. The usual method is to have one suction pump for all the boxes, up to even five or six, and to rely on regulating the vacuum on one or two of the boxes, in order to control the sheet. This is not satisfactory, because the moment the vacuum is altered on one box it is automatically altered on all the others.

The suction pump attached to vacuum boxes has to deal not only with air passing through the sheet, but also with a large quantity of water, and up till recently very little attention seems to have been paid to this point.

There is a tendency, however, nowadays for a large suction pump to be

employed with a large receiver between the boxes and the pump. The bottom of this receiver has a drain-pipe leading to a water pump which draws the water away from the receiver as it enters from the boxes, and leaves the air pump to deal only with air, which is drawn out from the top of the receiver. By adopting this method a much more satisfactory vacuum is obtainable, and when the vacuum is altered on any one box it does not affect the others as readily.

There is also another method in which barometric legs or syphon pipes are used in the system for the withdrawing of water.

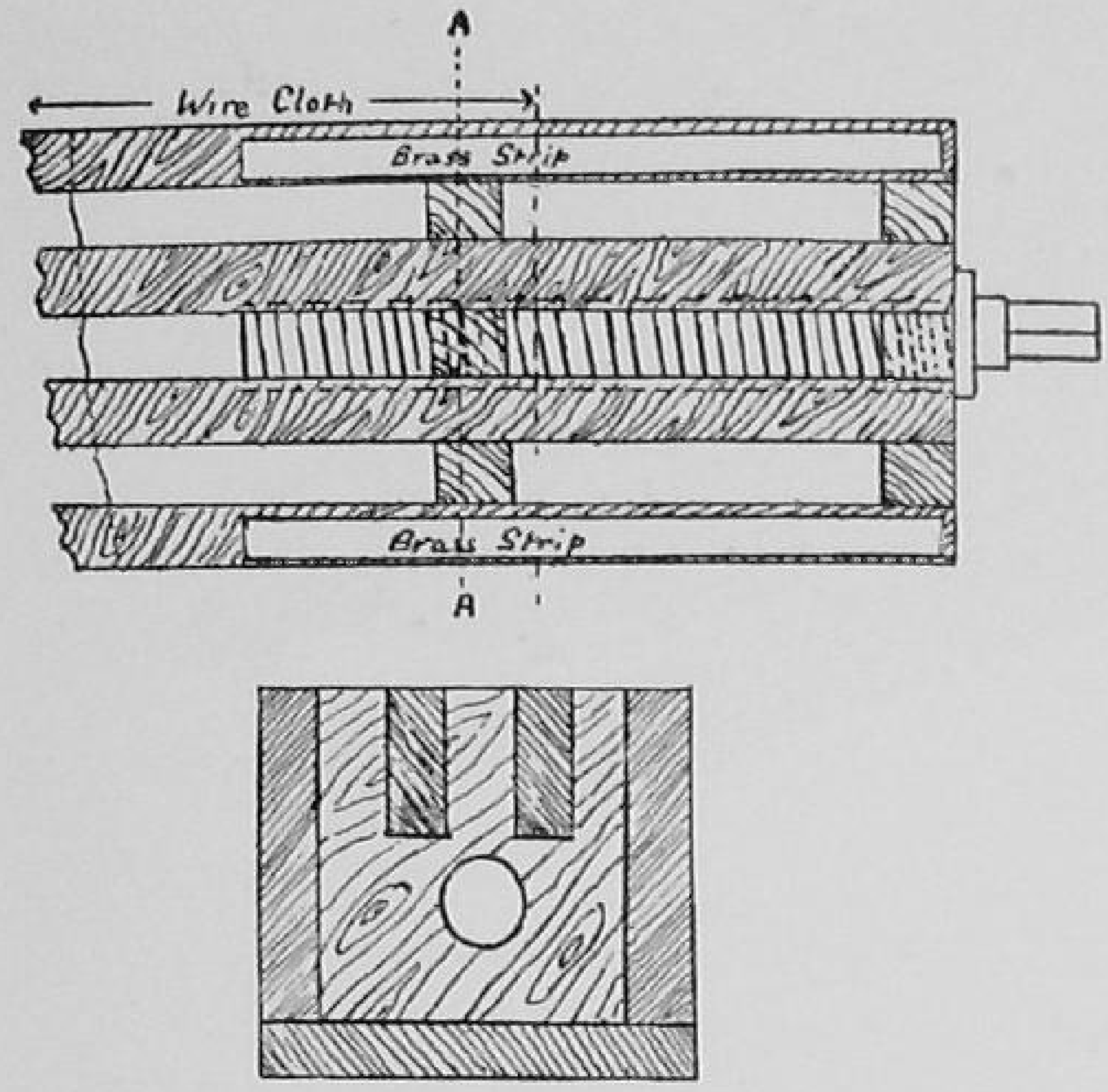


FIG. 123.—SUCTION BOX PLAN AND SECTION

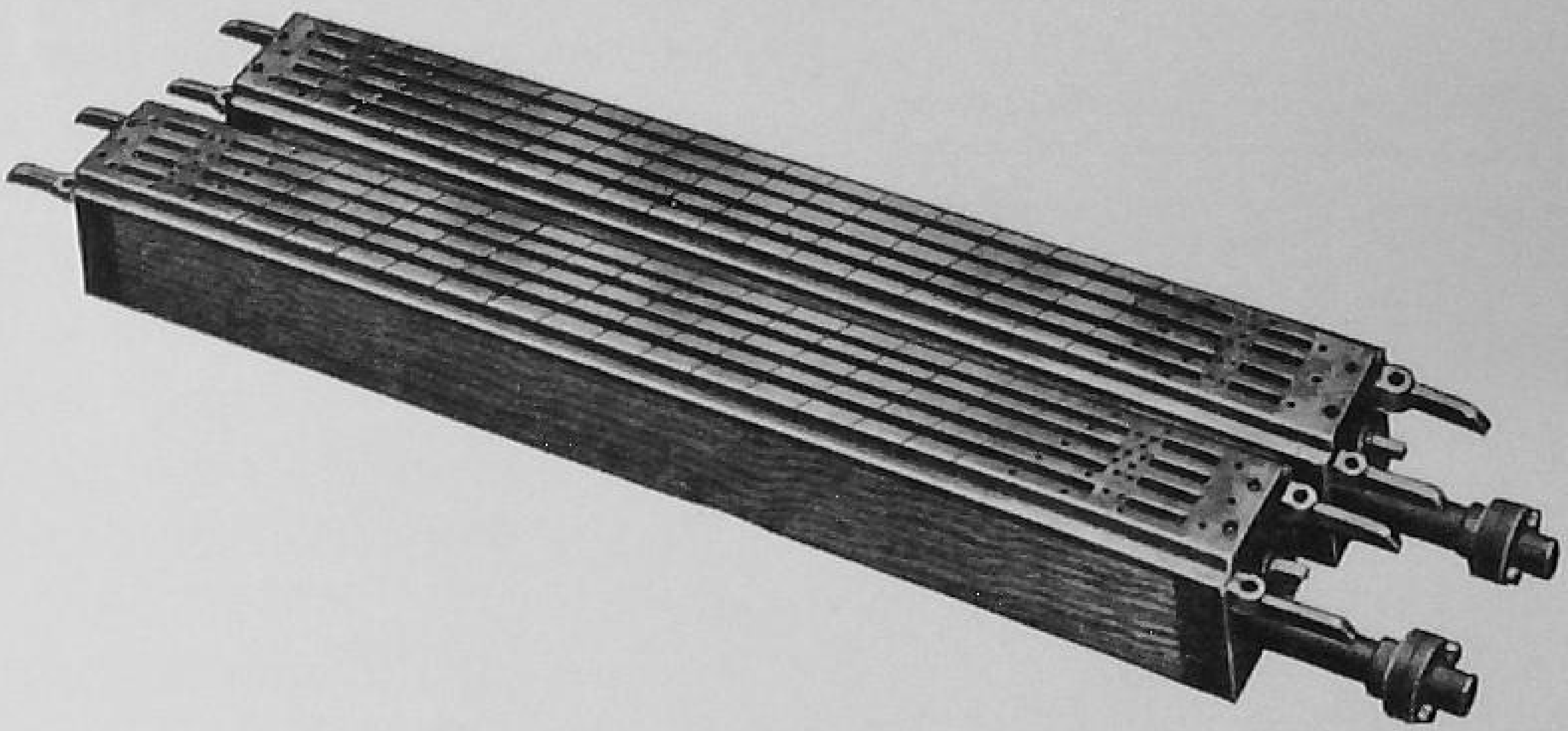
Suction Box Control.—To achieve the desired grading of suction box vacuum it is obviously better that each box shall have its own control device. The most simple method would be to allow each box its own barometric leg, provided sufficient water was removed from each box to fill the leg and produce the necessary flow. This condition rarely holds good on the later boxes.

An alternative may be sought in applying a separate pump to each box, although such a system requires a multiplicity of vacuum-producing units. Furthermore, it is necessary to install some suitable device to separate the back-water from the air drawn through the sheet since regular pumping, free from pulsation, is necessary.

Methods are available whereby a single pump can be controlled to give any desired vacuum at any given box in a regular manner. It is obviously not enough to put a simple air leak at each box since this would do no more than introduce a series of air leaks common to the whole circuit.

If a single pump produces a vacuum in a manifold header pipe and is connected to each box with a down pipe fitted with a sliding water outlet pipe at its lower end, such a system is possible (Fig. 127). Although there is a constant vacuum at the top of each down leg at its connexion to the header, the actual vacuum produced at the flat box is governed by the hydrostatic head of water in the down pipe. Since this head is variable by the movement of the sliding outlet leg, an easily controlled variable vacuum is available at each box. This arrangement has the disadvantage of requiring

an outlet pit double the depth as water head of the highest pressure difference required at the last flat box. For example, if it is desired to operate the flat

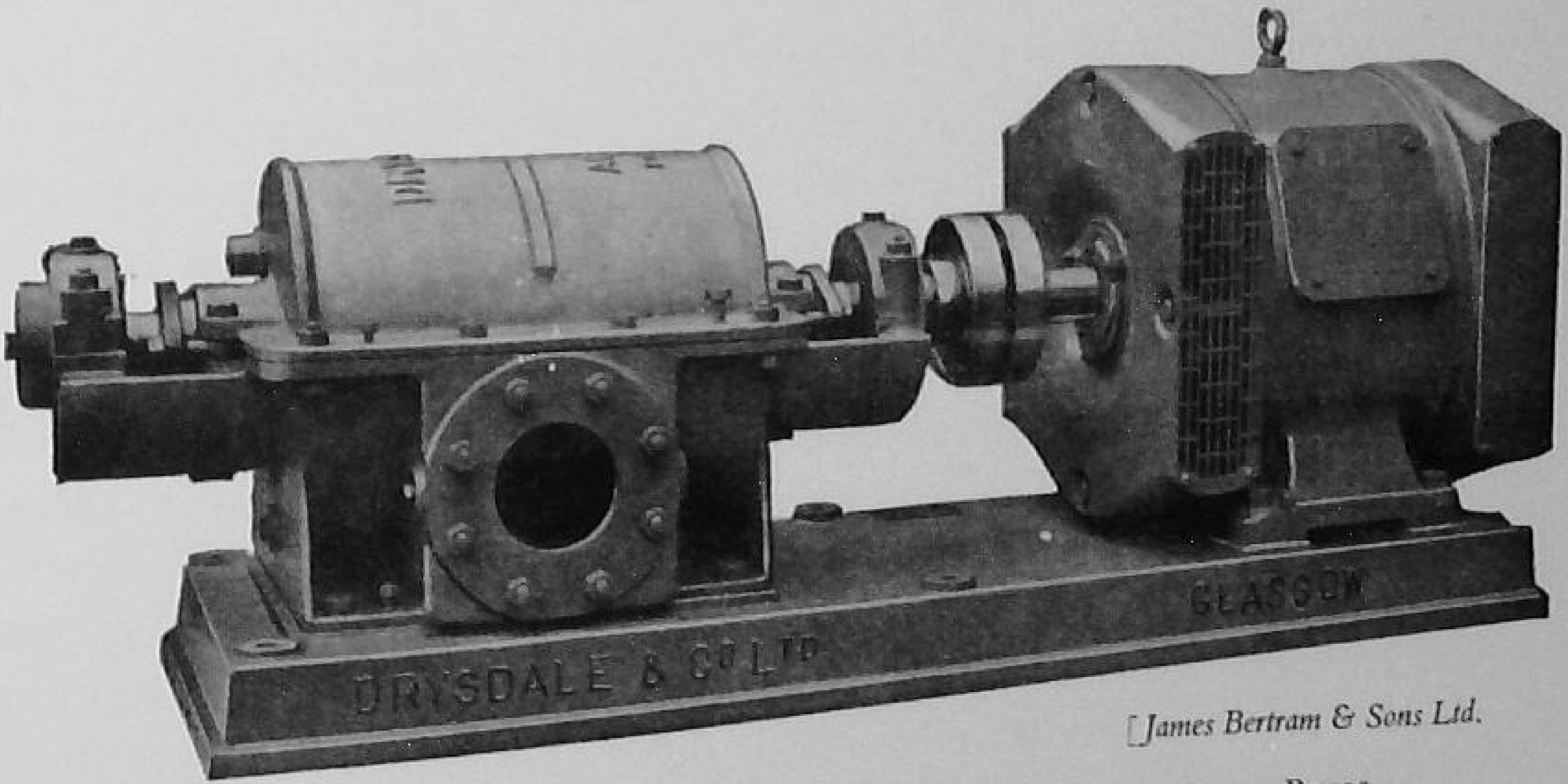


[*James Atherton (Sycamore) Ltd.*

FIG. 124.—NEW TYPE 'VULTURE' VACUUM BOX TOPS, WITH 'END ON' GRAIN FOR LONG WEAR
The top is in sections which can be easily fitted.

box at 5 inches of mercury (or $5\frac{1}{2}$ feet of water), it will be necessary, in order fully to accommodate the lowest level of the sliding outlet tube, to have a back-water pit some 11 feet deep.

This disadvantage is overcome with the Broughton suction box control system whereby each outlet to a suction box from the common vacuum

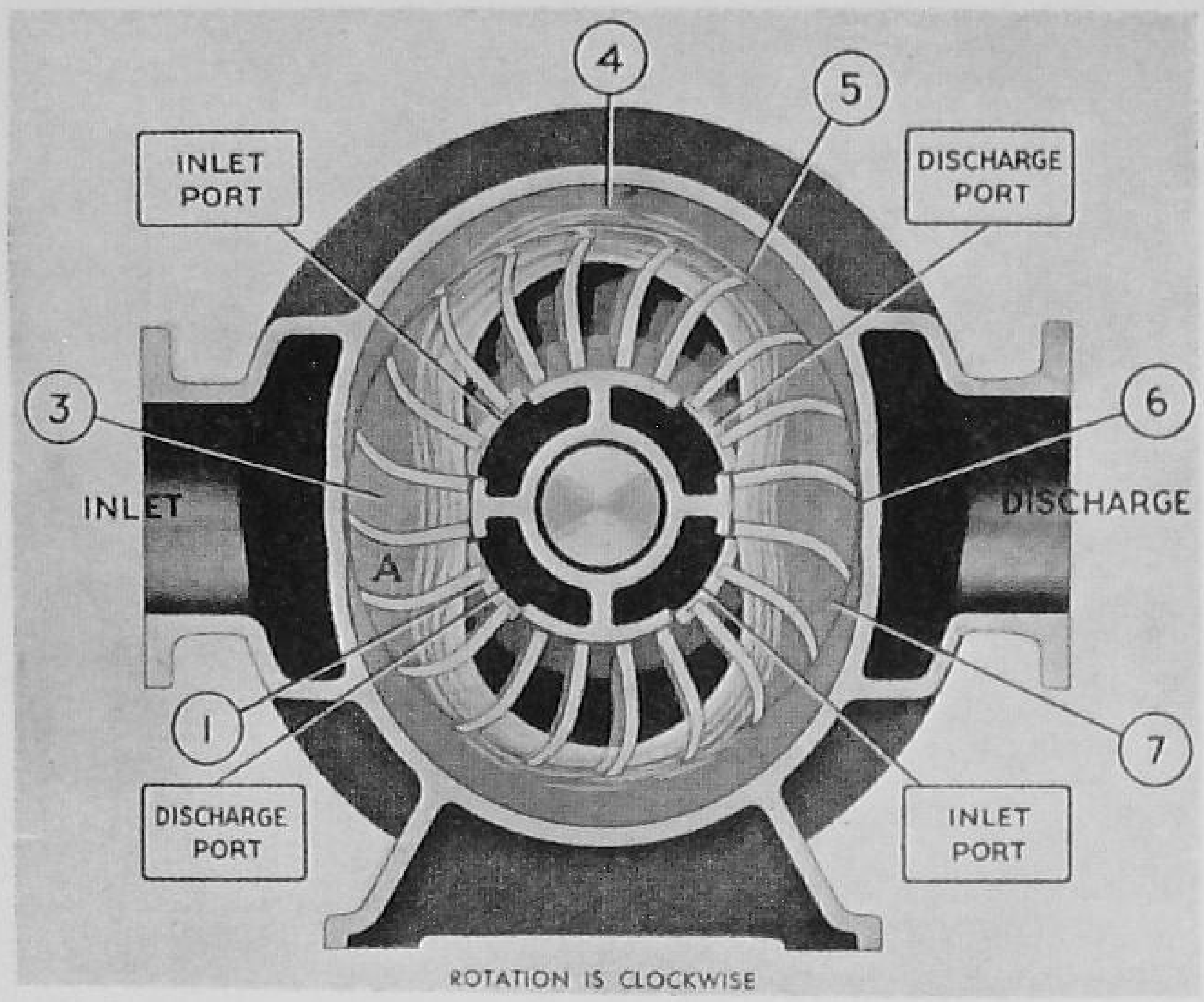


[*James Bertram & Sons Ltd.*

FIG. 125.—THE 'AQUAIR' VACUUM PUMP FOR SUCTION BOXES AND COUCH ROLLS
This pump is specially designed to deal with air and water.

header is fitted with its own vacuum regulator valve and so dispenses with the extra pit depth required for the movement of the sliding outlet leg on the

simple system. Control is then made by the individual adjustment of the individual vacuum regulator valves.



[*Walmsleys (Bury) Ltd.*

FIG. 126.—SECTION THROUGH NASH HYTOR VACUUM PUMP FOR USE ON SUCTION ROLLS AND SUCTION BOXES

We are still of the opinion that to have infinite control over the sheet when making fine papers, *a separate vacuum pump to each box is desirable.* The chief difficulty, however, is to get a sufficiently small pump, which is so constructed that it will stand up to the long hours of usage necessary on a paper-machine, and deal equally effectively with air and water.

Some machines still have steam ejectors on their vacuum boxes in place of air pumps, and these give excellent results, but they are extravagant in steam, and they are sometimes blamed for being responsible for making pin-holes in the paper. The least costly arrangement is to employ a barometric leg. Where the machine is built on the first floor and has a deep basement, it seems that there should be no difficulty in adopting this method, especially as the vacuum required on a suction box is never very high, and where there are long runs on the same furnish with the same amount of water.

When a wire is being changed, all the boxes should be cleaned, examined and tested for loose or worn bars or protruding ends, and if necessary these should be carefully planed level, or changed by a man experienced at this work. All bars with hard, soft or damaged places, or with knots, should be discarded, as they will make ridges in the wire and cause loss of suction.

To obtain efficient and steady suction, the boxes must be carefully levelled to each other and to the last tube roll. The guide roll should be slightly lower than the last box, little more than the thickness of the wire; the latter will not then be dragged hard over the edge of the last box and the guide roll will have a good grip of the wire and have more control over it. Sufficient space is left after the first box to run the dandy roll; all succeeding boxes should then be as close together as possible.

The first box is the most important. It is often said: 'The first box makes the paper'. While this is far from being correct, there is no doubt that the appearance of the sheet is mostly controlled by the regulation of the suction on this box. Too much suction gives a cloudy-looking paper, too little a crushed or greasy appearance; in the first case, the water-mark will be faint or absent altogether; in the second, it will be very muddled.

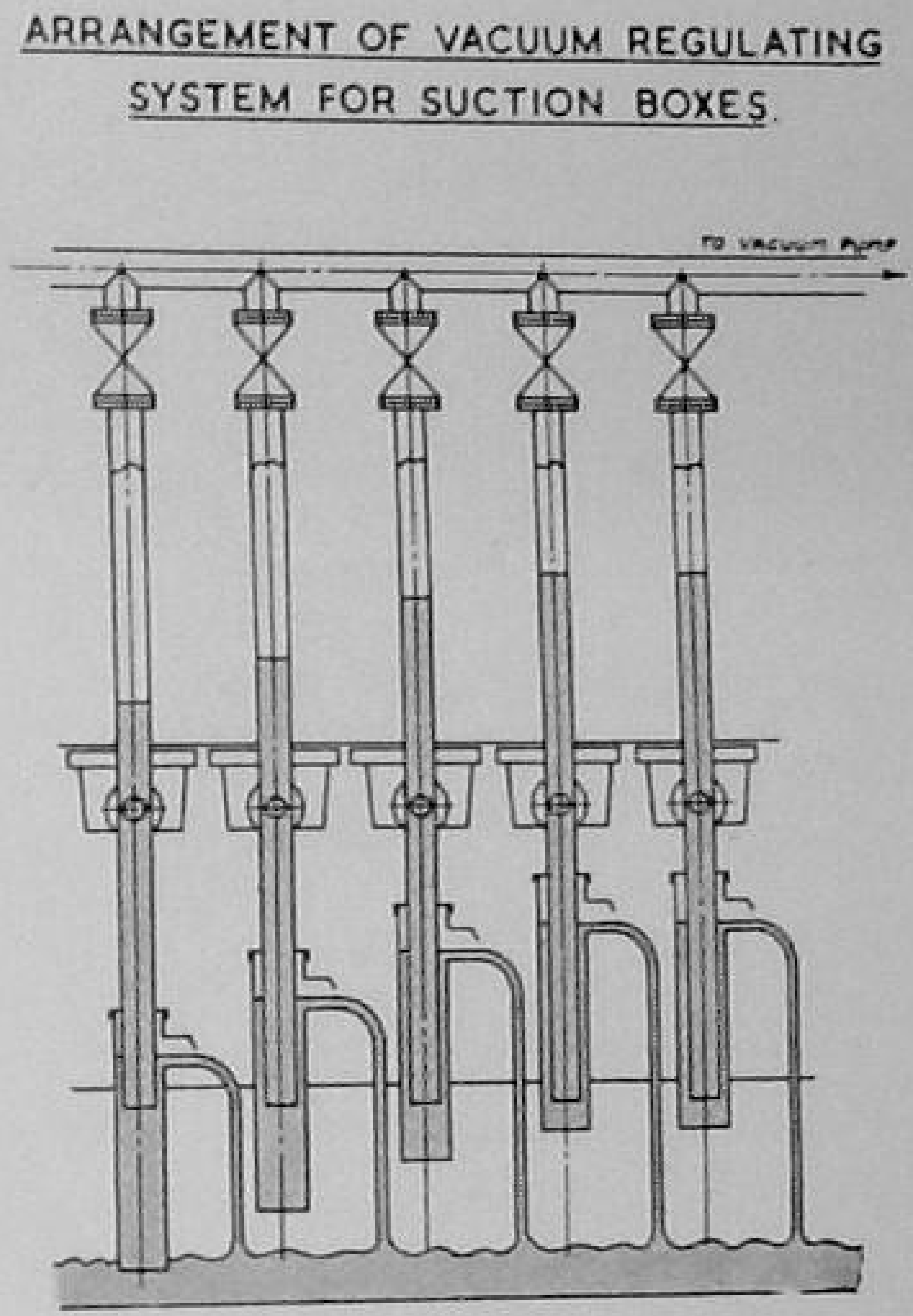


FIG. 127.—DRAWING SHOWING WATER LEGS AND AIR PIPE FROM SUCTION BOXES

Apart from the first box, which has this special function, the other boxes should have the suction divided between them as far as possible, though in practice it will be found generally that one will stand more than the other.

If one box is being overworked, it will commence to vibrate with a humming or howling noise. This has the effect of upsetting all the others, as the vibration will have the same effect as putting very excessive shake on the wire, and the stuff will 'flood' into the couch. The boxes, after the first, should be very close together, so as to keep up a continuous pull on the web, one box taking it up the instant the other leaves off, and leaving little space or time for the water to rise again to the surface of the sheet.

It is often advised in making certain papers: 'Do not use too much suction'. But no one *can* use too much suction without causing the wire and boxes to vibrate. If the machine is making paper with the boxes not drawing up to their 'maximum', it means the machine is running too slow, unless held back by lack of drying power or other causes. It should be put up in speed so as to be able to make the paper, and no more, with all possible suction in use. Of course, wear on the wire is increased, *but so is production*, and a paper-mill is not run to keep a wire on the machine for a long time, but to get the greatest possible output of paper in the shortest time, and of

the best quality. With regard to the latter, the drier the stuff can be made before it goes to the couch the more bulky and less wire-marked it will be. The couch-roll jackets and felts will last longer and the felts will not get dirty so soon. There will be fewer breaks at the presses and the whole work of the machine will be made easier. Therefore *in all cases* work your suction boxes, after the first, to the utmost limit of their capacity without vibrating them. Very often a good water-mark is crushed and made dull by the stuff being too moist when going into the couch rolls.

While dealing with suction boxes it should be mentioned that when a suction couch is in use, it is possible, and indeed often desirable, to leave much more water in the sheet after the last suction box than would be possible when a top couch roll is in use. The reason for this, of course, is that with a top couch roll, if too much water is left in the sheet, there is a risk of crushing at the couch. With a suction roll this trouble does not arise, and the excess water is removed satisfactorily by the vacuum of the suction couch roll.

Couch Rolls and Jackets.—The bottom couch roll is driven by the gearing and pulls the wire round. The top couch roll gives the first pressure which squeezes the pulp into the first semblance of a sheet of paper. The bottom roll is strongly built with a brass shell well stiffened with spokes and ribs. The top roll is greater in diameter and may have a brass shell or may be built of mahogany. Both rolls are, or ought to be, slightly *crowned* to work a certain weight at the spindle ends. Couch rolls are not set right on top of each other; the top roll sits well into the wire, for the reason that pressure of the wire against the circumference of the roll starts the pressure which culminates in the hard nip between the two rolls.

Though no water can be seen to be squeezed out until the nip is reached, there is no doubt that the pulp comes under the pressure sufficient to give it a certain stability and allow more weight to be put on the top couch roll. Most modern machines carry the top roll on swinging brackets, and levers for additional weights are attached to these. This is quite a mistake. More efficient couching can be obtained by putting the connexions for the levers on the spindle itself so as to bring the line of pressure through the centres of both rolls as nearly as possible. Many machines do not use a cover on the bottom roll. This may not matter for cheap papers, where wire-marking is not considered of much consequence, but it is false economy where fine papers are concerned. A cover prevents crushing, gives more bulk and a closer under side, and does not obliterate the water-mark to the same extent as a bare roll does. This is accounted for by the increased pressure surface owing to the 'give' of the woollen cover.

When putting on a new cover, the roll should be thoroughly cleaned with

hot water and the perforated holes in the shell cleaned out. If the water has been hot enough the roll will soon dry, or it may be wiped dry with a clean rag. The end over which the cover has to be drawn requires special attention, lest any bit of stuff or grease or chip of wood from the wooden end be pulled in and thus make a lump inside it. The cover should be temporarily fixed at the front side. It must then be pulled tight to the back side and permanently fixed there. The front side is then loosened and also pulled tight and permanently fixed. Whether it is tacked on to the wooden ends or roped on, it should be free to travel round the roll. Boiling water is necessary for the proper shrinkage of a new jacket, and quantity should not be stinted. If the cover has a nap—though this is not a necessity for a bottom roll—it should be in the running direction of the wire, so that the drag of the latter smooths out the fibres instead of ruffling them up. Sometimes a cover is tight and difficult to pull over the roll. Powdered starch or dry china clay well rubbed over the roll will help to make it slip on more easily. But if this happens often, the manufacturer should be notified and will be able to correct the size. After the cover has been shrunk, it is very necessary to go all over it carefully with the fingers lest there should be any hard knot in the wool or any substance underneath. Hard knots and wood splinters are not uncommon in covers and should be picked out with a sharp-pointed knife. Neglect of this precaution means a ridged wire in the space of an hour's work. This applies to both coucher covers.

It will greatly assist the starting of a new top jacket if the nap is gently brushed the running way, more especially on the two places where the jacket has been folded, and which have a tendency to stand up. If the covers are tacked on to the wooden ends, the latter must be perforated to allow the escape of the water coming through the perforations of the shell, and holes correspondingly punched in the covers. If roped on, the water will find its way through the open folds between the stitches. It sometimes happens that a cover works over one end of the roll. This may be owing to weight being applied unequally on the levers, insufficient shrinkage or to the cover not having been pulled tight from side to side. If correcting the weights does not send it back again, the best remedy is to loosen the tacks and refix, or put in a fresh rope, tighten up and apply hot water to the rope. Rope for this purpose can be obtained which tightens up and remains tight with the application of moisture, and roping is the quickest and safest method of fixing. When first put on, the coloured line of the cover will be approximately correct across the roll, but later on will show a bend in the centre. This is to be expected from the slight crown of the roll and the fact that the wire is tightest in the centre. But if one side should take the lead a little

there is no cause for alarm. It may be that the guard board is not so hard down, or so well fixed, or the inclination of the couch rolls may not be exactly correct at both sides. The roll may be more smooth at one side than the other, or the weights unequally adjusted. If all arrangements are fairly accurate, the difference in the line will be very slight, and will only go a short distance and may be discounted. But if the line continues to go farther off the straight, the machineman may be sure that some one or more of his adjustments are seriously wrong, or the inclination of the two rolls requires skilled attention and correction from the engineer.

In starting up with a new top jacket, unless the stuff is very 'free' and can be well dried at the suction boxes, it will be found that the new nap picks up fibres from the sheet. These accumulate until a small, flat patch of pulp is formed, and a new jacket may be covered all over with these patches in a few minutes.

The best remedy is to have the guard board well adjusted and hard down at the start. (It should be eased off again as soon as the jacket has become 'seasoned'.) The suction should be used to the utmost and as little weight as possible put on the roll. If the cover is run for a few minutes before starting up, with a hot mixture of resin size and china clay in the water channel of the guard board, there will be less trouble of this sort. Where it is possible, warm water, in place of cold, should be used in the water channel to clean off the patches of fibres.

In any case, it is best to start up with a new jacket at a speed slow enough to have a good control of the stuff at the suction boxes, and the wire as tight as safety permits.

Many machinemen prefer to run an hour or two with no water on the cover until it fills up to a working condition.

At all times it is inadvisable to rub the hair or nap of the jacket the wrong way if the stuff shows signs of going up the roll. Only a momentary improvement is obtained. A hot and strong solution of soda ash is far more effective, and this should be used when the cover requires cleaning, instead of using the force jet. As one of the chief causes of wear in a cover is the plucking out of the nap by the meshes of the bare wire, the new cover should, if possible, be started with a full-width deckle and full widths should also be run as long as can be arranged.

The Guard Board.—The function of the guard board is to clean and dry, as far as possible, the cover of the couch roll. As pressure is the integral part of this action, it will be readily recognized that its use will be the chief factor in shortening the life of the cover. For this reason various kinds of appliances have been tried, and many ways of fixing, pressing and covering the rubbing

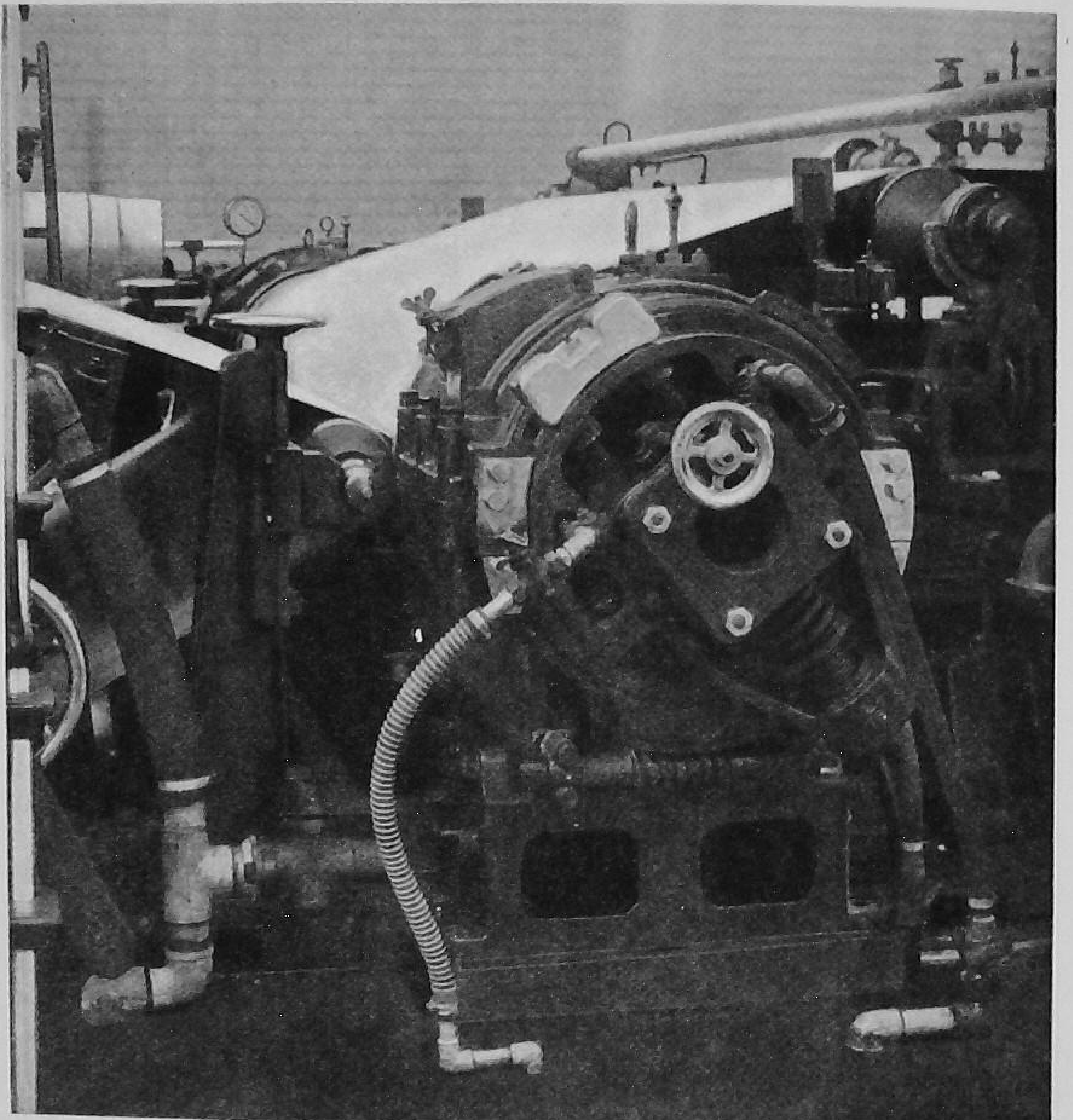
edge of the board have been resorted to. We will not go into details of these, or the special designs applied to high-speed machines, but confine ourselves to the types that are commonly used for machines in general. A guard board is usually constructed from one piece of good wood (pitch pine), strengthened and made rigid by another piece at right angles, fixed at the back of the board; or in some cases this is replaced by a rod of iron used as a 'stringer'. It is covered on the rubbing edge by a piece of old couch cover, and there are two ways of fixing and using it. It may be fixed to the brackets which hold the couch roll, sliding in a guide, and being pressed down by springs; sometimes there are no springs, and the board is pressed down by hand and fixed in position by bolts. If the brackets are of the modern type which swing with the couch roll, the board will of course rise and fall with the roll; but if the brackets are of the older fixed type, the roll is apt to lift the board and let water pass.

A board of this kind must be very carefully used. The machineman is sometimes tempted, when running very wet or fine stuff, to squeeze it very hard down on the cover, when he may very easily reduce the life of the latter by half. A safer and more efficient type is the swinging board. This is hung on pivots on the brackets and the pressure is applied by weights hung on short fixed levers on the back of the board. Being free to rise and fall, it does not require to be so heavily pressed on the roll, and the pressure is more easily controlled and observed. This kind, owing to the angle at which it touches the roll, has the advantage of allowing a deeper flow of water to be used to clean the cover, and therefore washes away any fragments of fibre that may come up the roll. A fixed board requires to be set opposite the point of pressure of the couchers, and the angle admits of a very shallow flow.

The board may be used without a cover, but though the wear of the jacket is less and the joint is more water-tight, the jacket fills up with size, loading and fine fibres, and requires frequent cleaning and blowing with the force jet. The efficiency of the couch roll is greatly reduced, and any saving in covers is nullified by the waste of time and extra 'broke'. The flow of water is supplied by a spray-pipe close to the guard board, but the spray must not play on the couch-roll cover, or it will raise the nap and the fibres will be pulled off by the board. A frequent cause of damage to the cover is that, when shutting down or starting the machine, bits of pulp or foreign matter stick to the roll, and become jammed in the board, cutting or scoring the cover in a few turns, or, passing the board in hard rolls, spoil the wire. Brushes or strips of old jacket are sometimes fixed in front of the guard board to loosen these and allow the water to wash them away.

A very good combination is a swinging board and a rubber-covered

squeeze roll just after the couch roll clears the board. Then the board may be used as a light cleaning agent and the roll will take the water out of the



[*Robert Fletcher & Son Ltd.*

Fig. 128.—Suction Couch Roll working on a Machine making Fine Tissues at High Speed

cover before it touches the paper, far more effectively than a board can. With this arrangement higher speeds and more output can be obtained, without the necessity of increasing couch-roll weight.

Suction Couch Rolls.—The suction couch roll (Figs. 128 and 129) has now almost superseded the couch press, and although some people still use the press method of couching, it seems that the suction roll will soon be universally employed.

The suction roll has many advantages over the plain couch, the chief of

which is that there is no top roll and no jacket. The eliminating of jackets saves a great deal of time, and a great deal of spoilt paper, because jackets

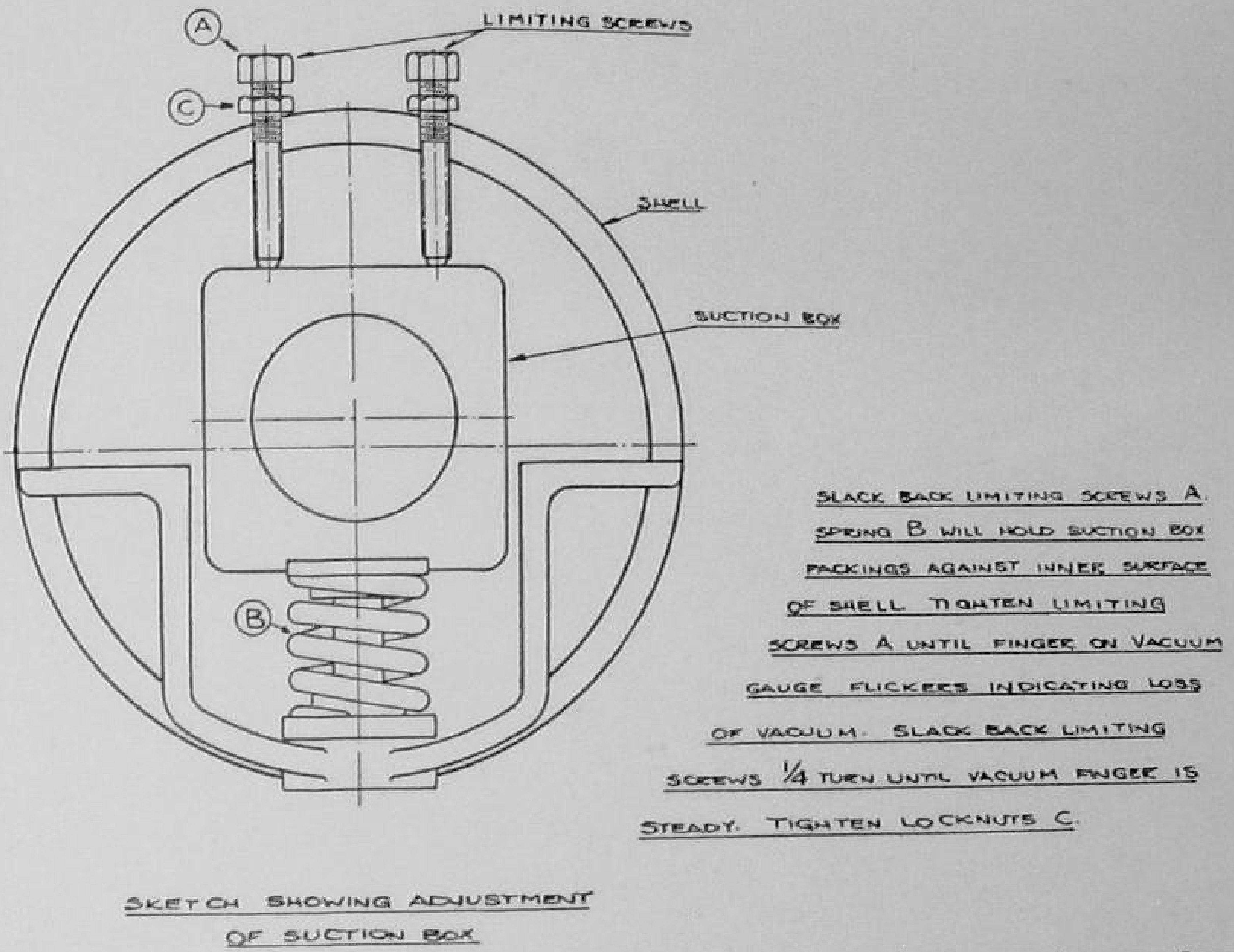


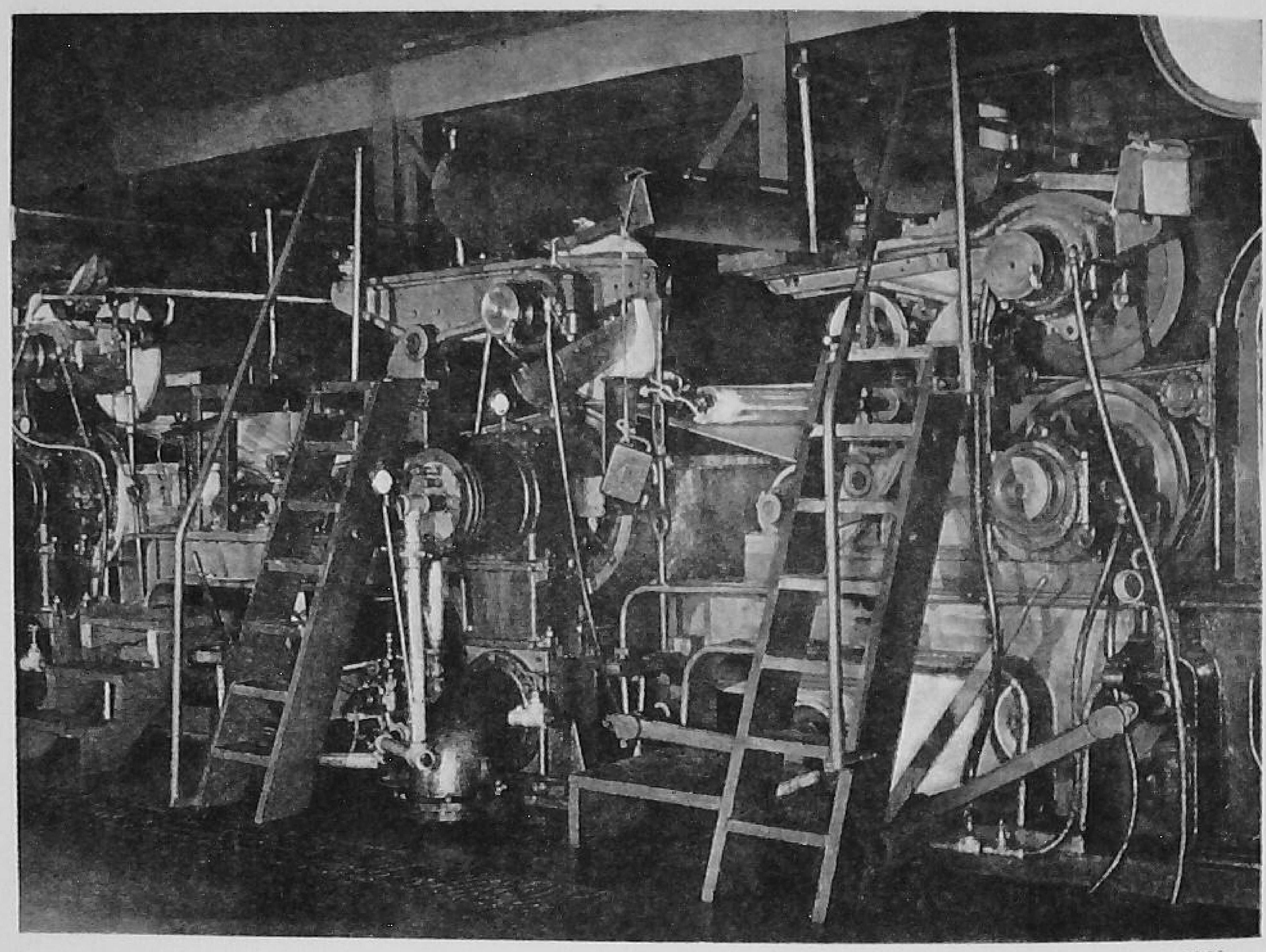
FIG. 129.—MILLSPAUGH SUCTION ROLL, SHOWING SPRINGS FOR HOLDING BOX UP TO SHELL AND ADJUSTING SCREWS

always gave some trouble when starting up new, and further trouble when becoming worn. The elimination of the top roll has entirely done away with crushing of wet stuff, and the damage done to the wire by the pressure of the nip, due to lumps of stuff or foreign matter, has entirely disappeared.

The guiding of the wire is much simpler and, in fact, presents practically no difficulty with a suction roll, and the danger of running the wire out of square, due to uneven weights on opposite sides of the couch press, does not arise when a suction roll is used. Much longer life is generally obtained from the machine wires, and in most cases a drier sheet is delivered on to the wet felt, which latter in turn naturally has a longer life, by reason of the fact that it has not so much water to deal with.

There are now several very satisfactory suction couch rolls available, and experience seems to show that they will run for many years without any attention whatsoever. While some of these rolls consume a fair amount of power through their vacuum pumps, very efficient pumps are now available, and the power consumed is nothing when compared to the efficiency of the roll and its many advantages in the saving of time and the maintaining of production at a high level.

Presses.—After passing through the couch rolls, though the sheet is now for the first time in a condition to be handled, it must be further pressed, so as to be so far freed from water as to stand the heat of the dryers.



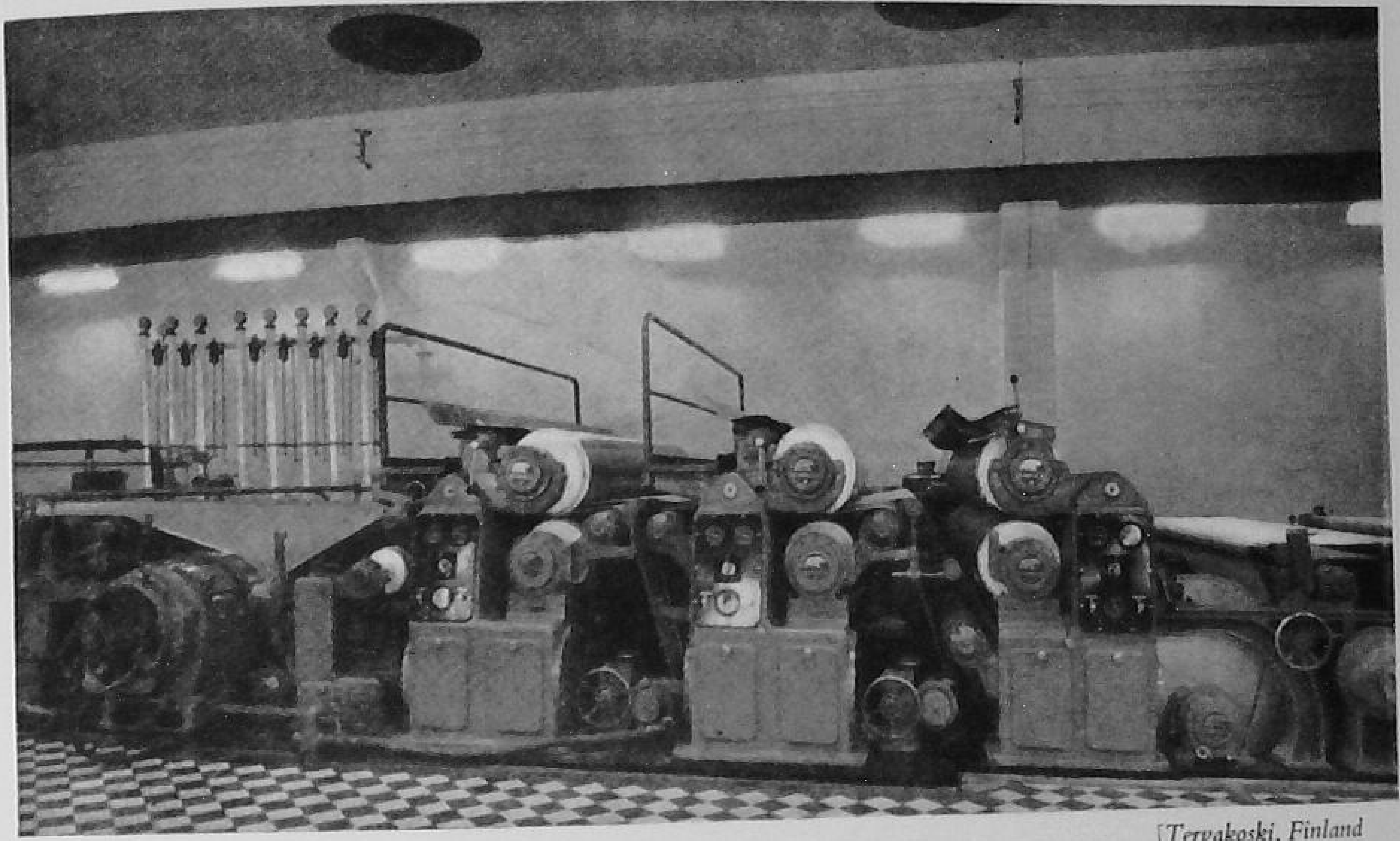
[*The Bagley & Sewall Co., Watertown, N.Y.*

FIG. 130.—PRESS PART OF LARGE FOURDRINIER MACHINE SHOWING SUCTION AND PLAIN PRESSES

This is accomplished by running it on woollen felts between 'press rolls'. Usually two sets of press rolls and felts are used, though machines designed for high speed or for making special papers may have three or four. Since pressure means loss of bulk, it is not desirable for machines making high-class paper or bulky printings to have more than two sets. The first set of press rolls and the 'wet felt', as it is called, do the bulk of the work. The second set is so arranged as to smooth out the wire mark.

Underneath the bottom roll is placed an oblong box or tray to catch and lead away the water squeezed from the web. The bottom roll is driven and the pressure of the two rolls pulls the felt round. Before the felt and paper enter the nip there are often air pockets between them. A small suction box with perforated holes on the top is arranged at this point and extracts the air so that no wrinkles are formed in the paper. Sometimes, a roll of 2 to 3

inches in diameter, called a 'blow roll', is used to raise the paper from the felt and allow the air to escape.



[Tervakoski, Finland

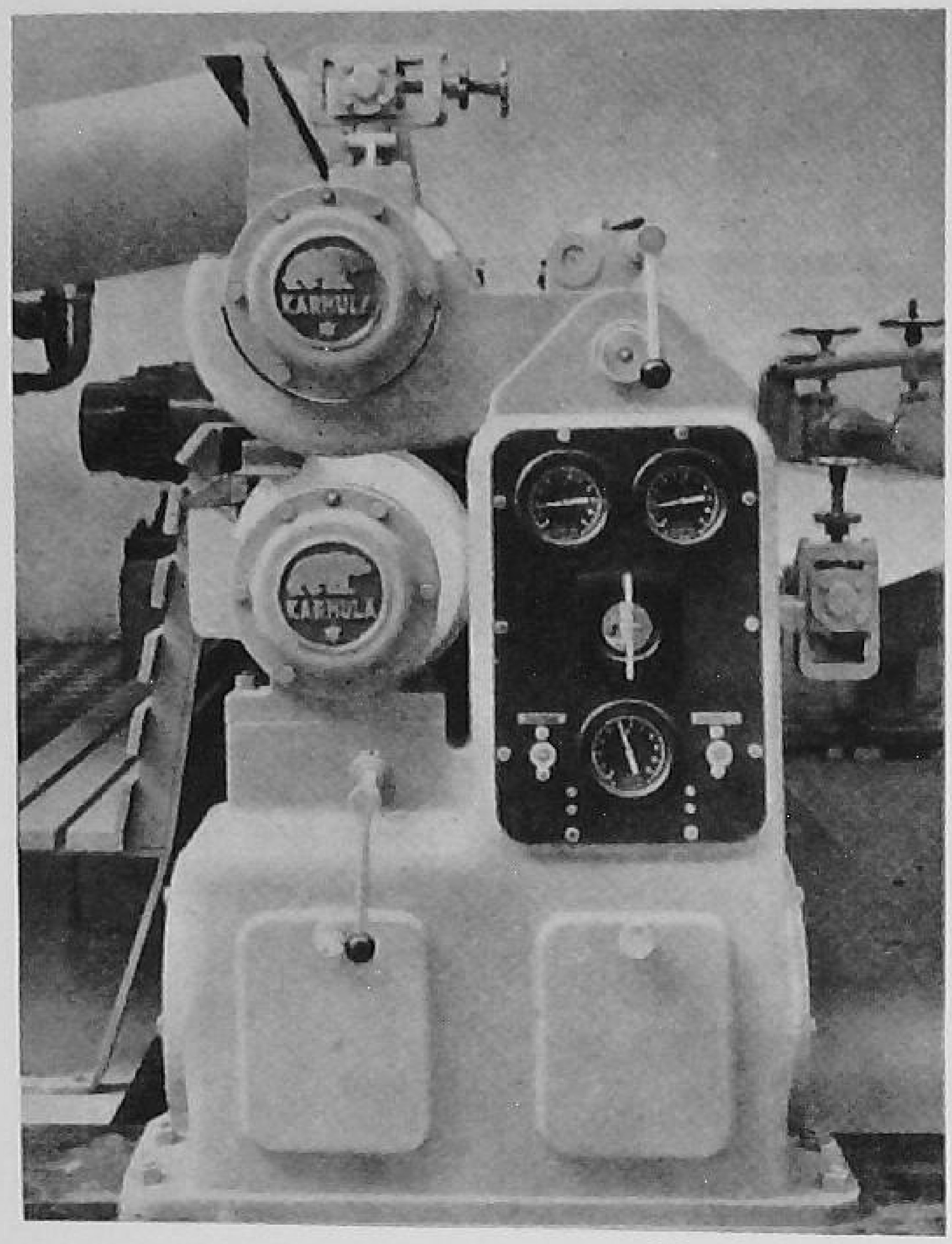
FIG. 130A.—PRESS PART OF MODERN MACHINE FOR FINE PAPERS, SHOWING VERY ACCESSIBLE AND CLEAN DESIGN WITH PNEUMATIC CONTROL

Of late years, press rolls of granite have become popular. The cold, crystalline surface does not pick up 'greasy' or fine stuff as easily as the brass shell does. For this reason they are valuable for use with esparto, straw and mechanical fibres, which have very little strength or length to carry them over the machine. They are usually run with non-metal doctors to obviate 'pencilling'.

The top press roll may be made of iron, brass, granite or wood. The bottom roll is usually rubber-covered. Sometimes two brass rolls are met with, but these are very destructive to felts, since a small lump passing through will cause the felt to be damaged. The rubber covering of the bottom roll lessens this danger considerably. With a rubber-covered roll there is a less severe nip of the felt and paper, but even so quite satisfactory removal of water is effected and longer life obtained from the wet felts. The top press roll is fitted with a doctor, either iron or composition, the purpose of which is to clean the roll and also to hold up the stuff which may stick to the roll and prevent the sheet from going round if a break occurs.

Suction Presses (Figs. 130 and 131).—The tendency is nowadays for the ordinary press to give way to the suction press. This press consists of a bottom

roll containing a suction box and perforated shell, which is the same as the suction couch roll, with the exception that it is usual for this suction roll to be rubber-covered over the bronze shell. Where suction presses are used, it is not generally found necessary to have such a heavy top roll, or to use such pressure, as was often found necessary with the ordinary press. Some paper-makers maintain that if they had the option of having a suction couch or a suction press, they would prefer the suction press. The reason for this is that all felt troubles are practically eliminated, very much longer life is obtained from the wet felts, very even drying of the paper results, and a much more uniform sheet is obtained. It is usual to have 14 to 24 inches of vacuum in the suction roll, and the hardness of the rubber used varies between 30 P-J. and 50 P-J., the first being comparatively hard, and the second much softer.



[*Tervakoski, Finland*

FIG. 130B.—MODERN STRAIGHT PRESS ON MACHINE MAKING FINE PAPERS

The pneumatic gear is enclosed in the frame, and the panel contains the gauges showing the pressure being applied.

The Dual Press (Figs. 132 and 133), which is now being taken up in this country, has actually been in use for some years in America.

It consists of three press rolls, two of which may be suction rolls, with a plain roll in between, as clearly shown in the photograph and drawing.

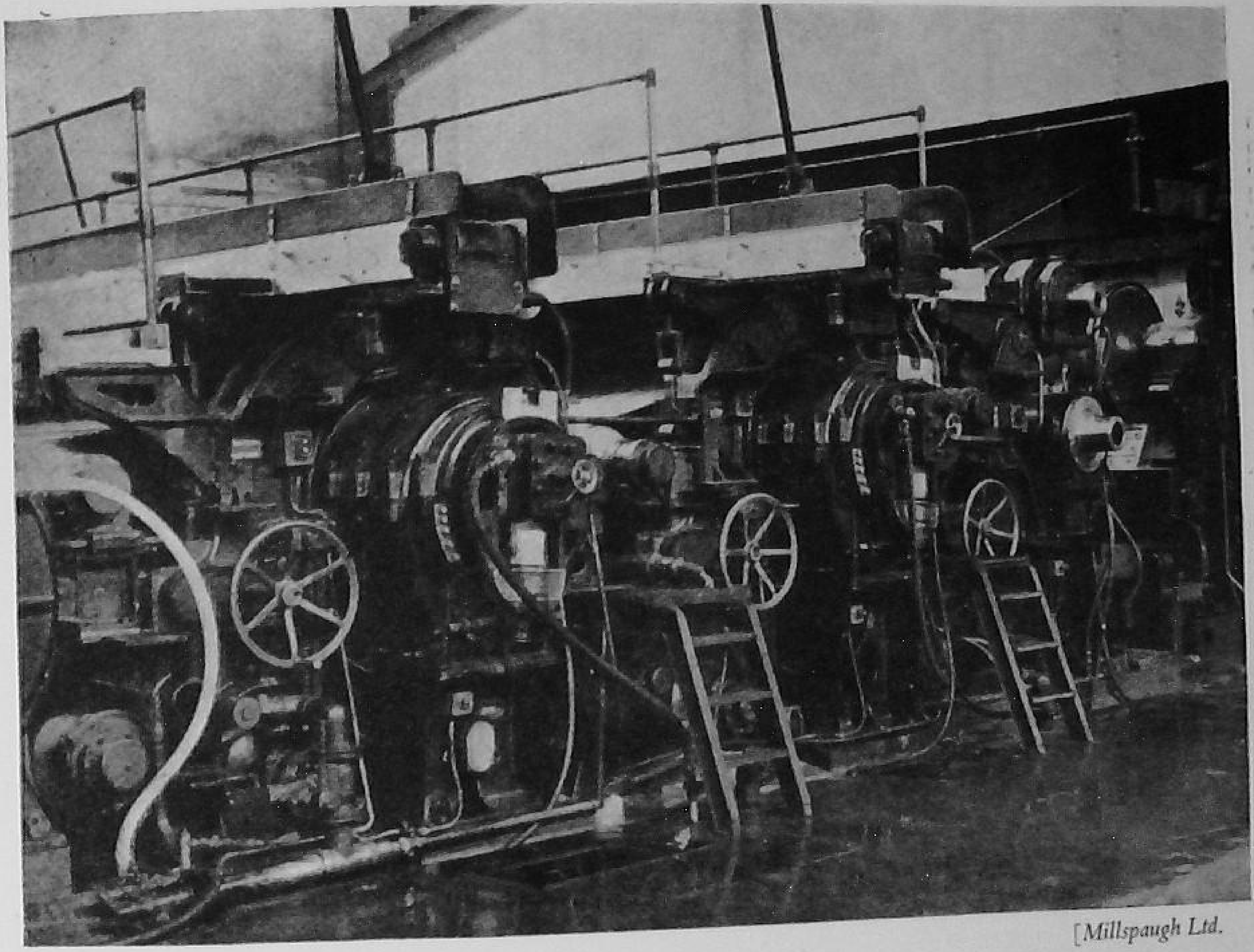
There is a great saving in space with this arrangement, but there are also many other advantages claimed by those who are using this design.

The pressure is applied laterally by levers, instead of vertically, and much greater felt life is being obtained.

A doctor blade should be made to move from side to side by traversing gear; the purpose of this is to prevent pencilling or scoring of the roll by any particle of grit becoming embedded between the doctor blade and the roll. The doctor is hung on pivots to enable it to be cleaned and refitted.

Stacked Press.—The transfer of the wet sheet from the couch to the first

press, which occurs whilst the paper is in its weakest condition, is a source of trouble, and it is in order to mitigate these difficulties, and to simplify



[*Millspaugh Ltd.*

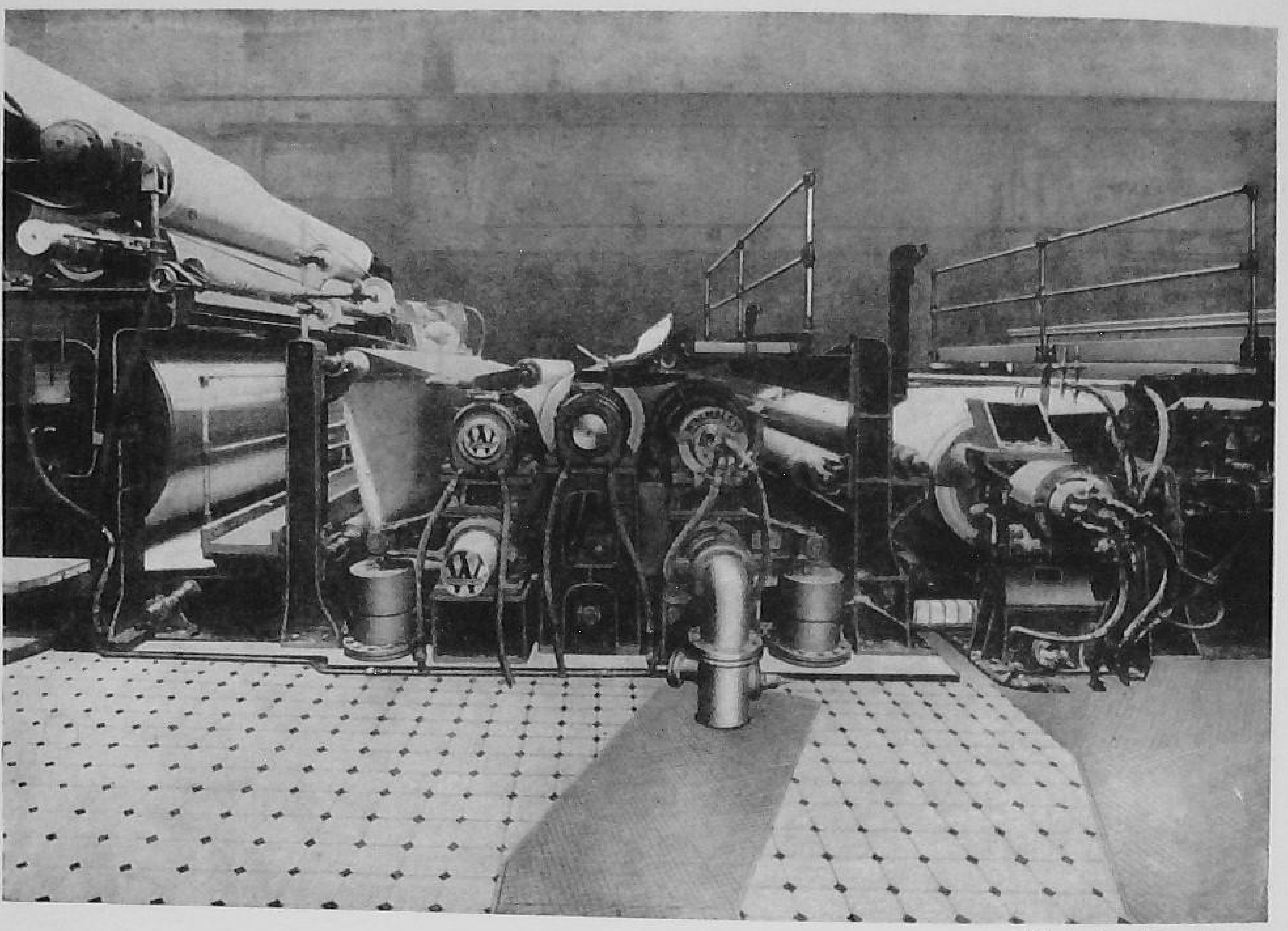
FIG. 131.—PRESS PART OF LARGE FOURDRINIER MACHINE EQUIPPED WITH MILLSPAUGH SUCTION-PRESS ROLLS

and advance paper-making generally, that new press arrangements have been introduced eliminating the draw from the couch and first and second presses. In certain cases it is quite practicable to take the sheet automatically from the wire to the first dryer without stretching the paper, the first draw being from the first to the second dryer.

Vacuum transfer from the wire is incorporated in the majority of these new press assemblies, and this innovation is not only important for handling thin papers at higher speeds, but will also enable heavier sheets of low wet strength to be handled with the minimum of wet end breaks, or allow a lower sulphite content without the loss of production due to breaks now experienced in high-speed paper-making.

Fig. 134.—This arrangement has proved successful on machines producing light-weight tissues, imitation parchment, greaseproof, writings, newsprint, etc., etc., the transfer from couch to press being fully automatic.

The wire is extended over a drive roll, which is connected through gears to the suction roll, and driven from a common indrive shaft.



[*Walmsleys (Bury) Ltd.*

FIG. 132.—DUAL PRESS ARRANGEMENT, SHOWING ONE SUCTION ROLL AND TWO PLAIN ROLLS ARRANGED TOGETHER
The third roll can be arranged for suction if necessary.

The bottom press roll contacts the extended wire; the sheet is picked up by vacuum on to the first press felt, and carried through the first vacuum nip between two felts. After passing the first nip, the paper is again transferred by vacuum to the second press, the felt of which carries the sheet through the second vacuum nip.

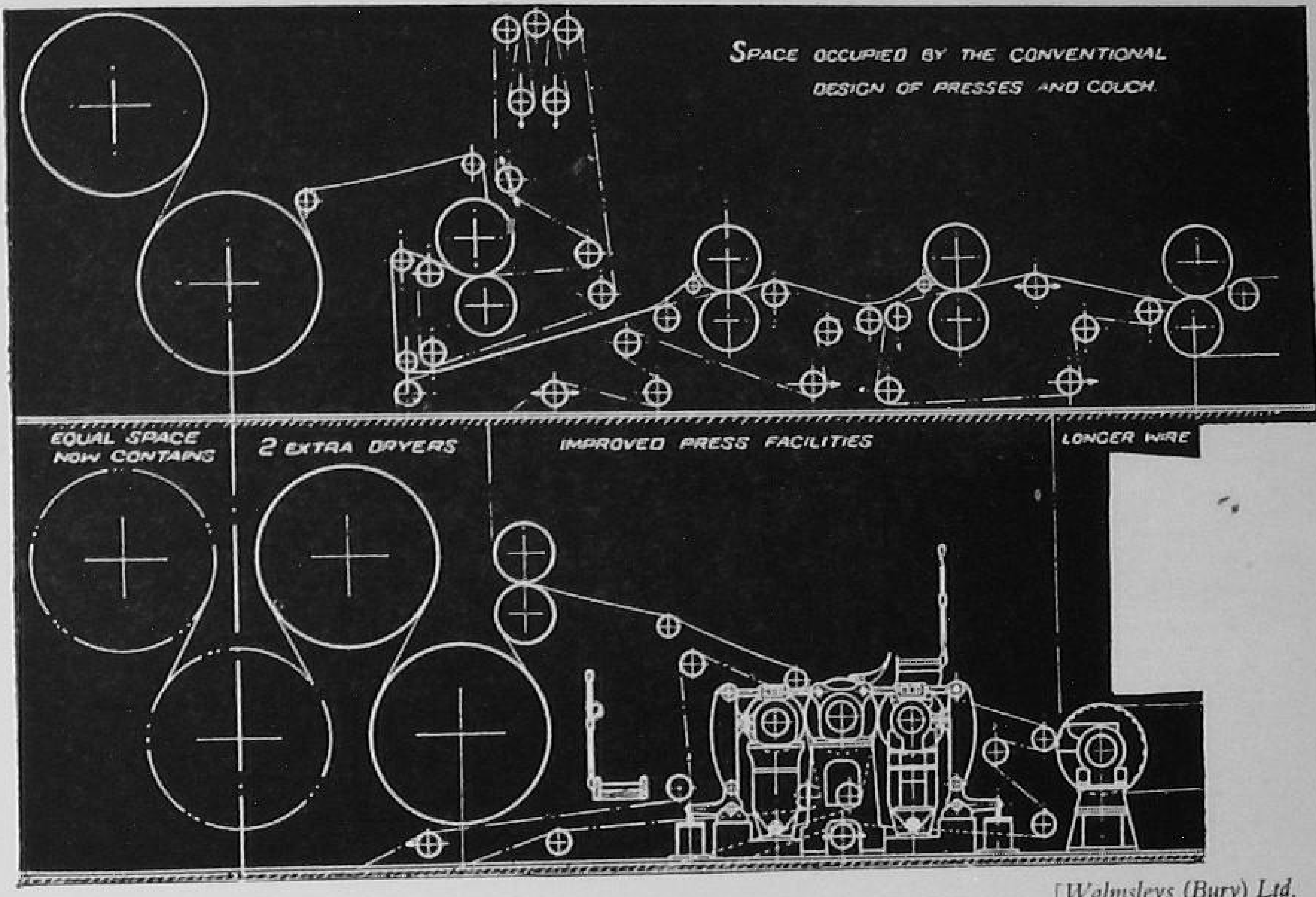
The top side of the sheet, as distinct from the wire side, comes into contact with the unfelted top roll, from which the sheet is doctored off and fed to the dryers in the conventional manner.

The drive roll can be raised or lowered at will by hand-wheel and worm-gear operation or, alternatively, by electric motor with push-button control.

Provision has also been made for lowering this forward roll electrically, in the event of the couch and press drives failing, so that the wire and felt are immediately separated.

In operation, the stock is fed on to the wire with the drive roll in the

'down' position, and, as soon as the stock is evenly spread over the wire, the drive roll is raised until contact is made with the bottom press felt, with subsequent transfer of the sheet to this felt.



[Walmsleys (Bury) Ltd.

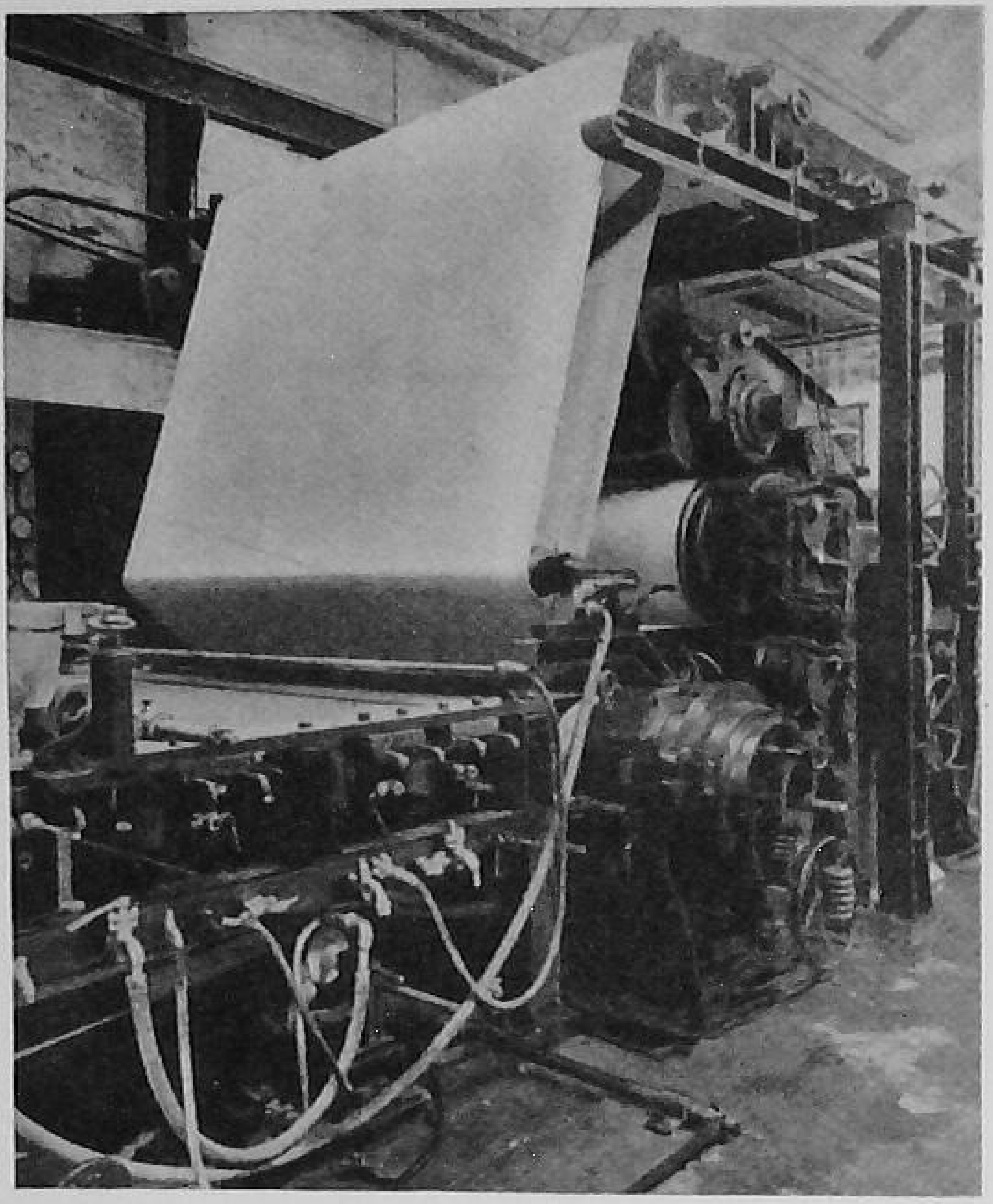
FIG. 133.—SKETCH SHOWING USUAL ARRANGEMENT OF PRESSES (ABOVE) AND DUAL PRESS (BELOW)
The saving in space is very considerable.

This arrangement constitutes a press part which eliminates stretch from couch to top press roll, automatically transfers the sheet and, by reason of its compact layout, is most economical in space.

Wire changing is a little more difficult than on a standard Fourdrinier. The couch with its forward wire roll is either cantilevered, or the assembly of couch and forward roll is designed to run out in the aisle.

The assembly shown diagrammatically in Fig. 135 gives an ideal press section for a medium-speed machine requiring two suction press nips, but not justifying the extra power required for the vacuum roll pumps necessitated by the stacked press. An assembly of this type offers many advantages. The sheet is automatically transferred by vacuum from couch and Fourdrinier to the press section. There is no draw between first and second press nips. One suction roll only is required for the two nips. The power required by the vacuum pump is a minimum. It is, of course, quite practicable,

where still better pressing is required, to have more than one 'Simplex' press, or it may be combined with subsequent presses.



[Millspaugh Ltd.

Fig. 134.—Stacked Suction Press, showing the Three Rolls and Wet Felt

Woollen Felts.—The provision of proper felts for the particular machine and paper to be made is of very great importance in every paper-mill, and most mills have their own ideas of the most suitable felts for their particular work. There is a wonderful variety of felts available to paper-mills, and the felt-makers are always ready to co-operate in every possible way in the provision of felts most suitable to the requirements of each mill. In fact, they sometimes wish that more standardization would be possible, especially in the lengths of both wet and dry felts.

A most important feature in the running of a felt is the actual arrangement of felt rolls, in order to have as few sharp break backs as possible, and the two sketches (*a*) and (*b*) in Fig. 137 will show two very different arrangements of the run. The arrangement shown at (*a*) has a lot of very severe bends in it, and is very hard on the felt. It should be the aim of the designers of the machine to have as few rolls as possible in the lay-out, as this reduces the number of points of contact, and is also very helpful to the machine crew when putting on a new felt. In the sketch (*b*) the run is very much straighter, and the only severe break back is in connexion with the stretching, and this, of course, is unavoidable.

The provision of a satisfactory guide roll is, of course, absolutely essential, and these should always be automatic because no matter how careful the machine crew may be, there are times when the attention of those responsible must be distracted from watching the felt, and many felts have been lost, or badly damaged, by running off the machine when the attention of the crew has been focused on some other urgent business, and in consequence no one would be really to blame.

The factors governing wear on felts are the number of times a point

on the felt passes between the nip of the press rolls. Added to this there is the friction as the felt passes over each felt roll in turn. The felt-makers should

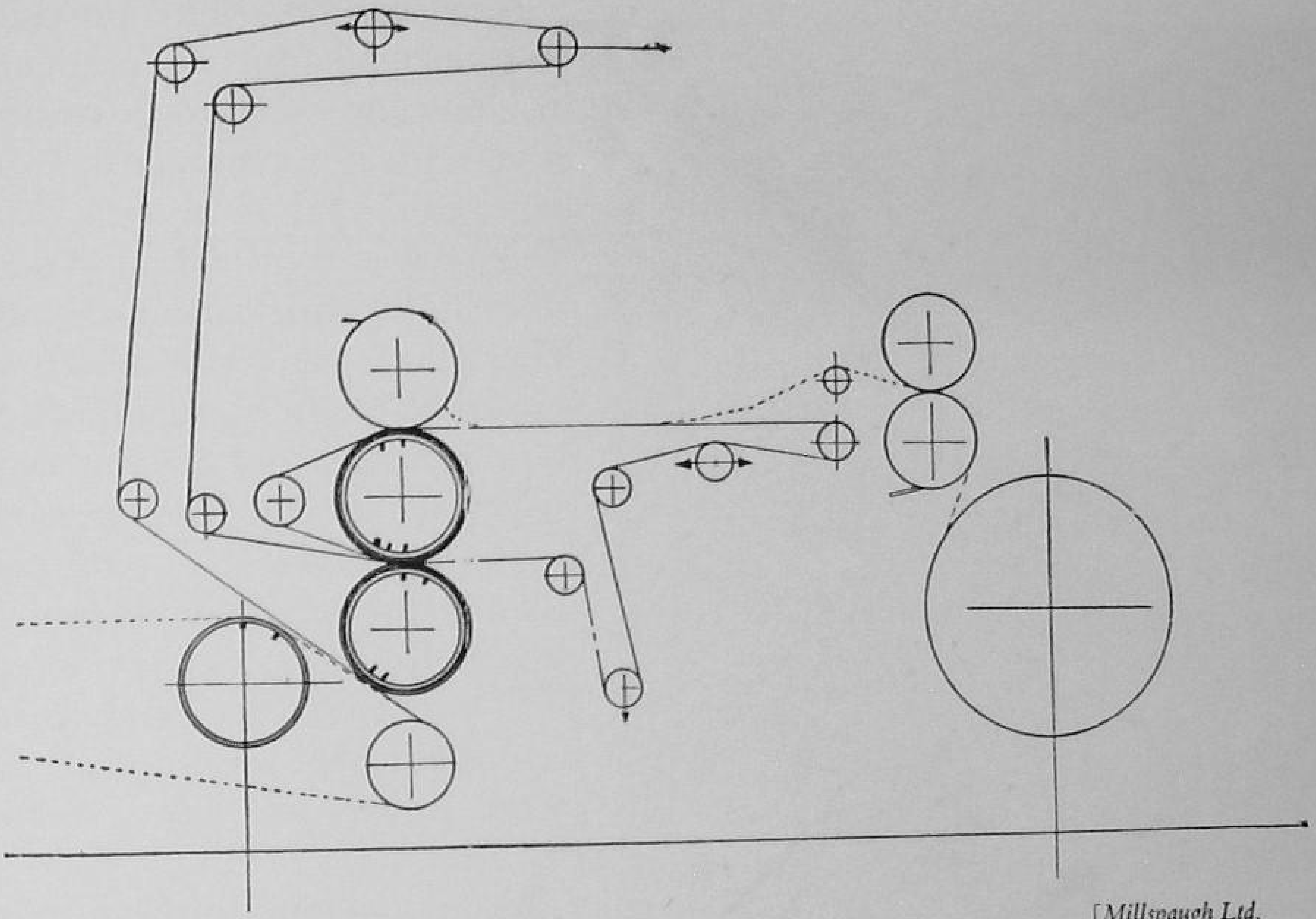
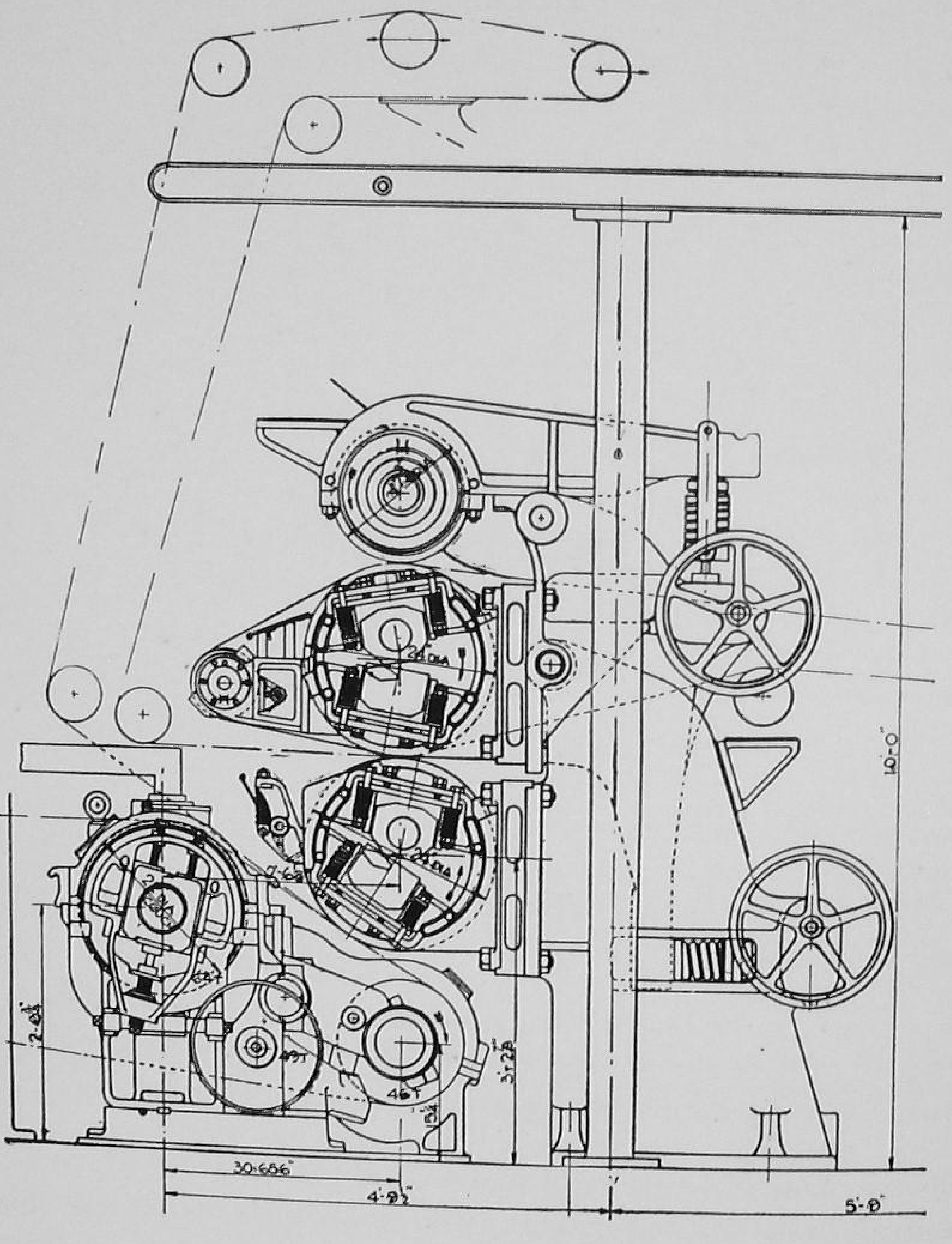


Fig. 134a.—Arrangement Drawing of Stacked Press, with Suction Couch, Vacuum Transfer from the Wire, and Suction Press Rolls

always be taken into the confidence of the paper-makers, and should be given opportunities to see the felts in operation, as in this way they are often able to make very useful suggestions. There is another factor which has a good deal of bearing on the life of felts, and this is the scroll or worm roll. These rolls are used to keep the felt spread out evenly and to assist it to run straight, and some of these rolls may be quite necessary. The use of them, however, should be reduced to the minimum necessary to give the desired result; and too high scrolls should be avoided wherever possible.

When starting up a new felt it has to be wetted out, and this should never be done with a hose-pipe. The reason for this is that the part of the felt which is wet first tightens up immediately, and then there are tight and slack places all over the felt, and great danger of wrinkling. By far the best way to wet out the felt is to have a spray pipe giving an even flow of water across the whole width of the felt, and this should be in front of the nip so that the felt carries a pool of water into the nip, and this is forced through the felt, giving much quicker and more efficient wetting.

Felts should never be run tighter than is absolutely necessary, because the running of a felt too tight has a very bad effect on its porosity.



[*Millspaugh Ltd.*

FIG. 134B.—DETAILS OF THE CONSTRUCTION OF THE STACKED PRESS SHOWN SCHEMATICALLY IN FIG. 134A

It is sometimes found that after a new felt is put on, the machine has to be run more slowly, and the paper is not right for some hours. This is often due to the fact that the nap stands up too much, and takes some time to be flattened out. If this is explained to the felt-maker, he will flatten the nap

down when finishing the felt, and then the paper-maker can start off at normal speeds with the felt acting perfectly well.

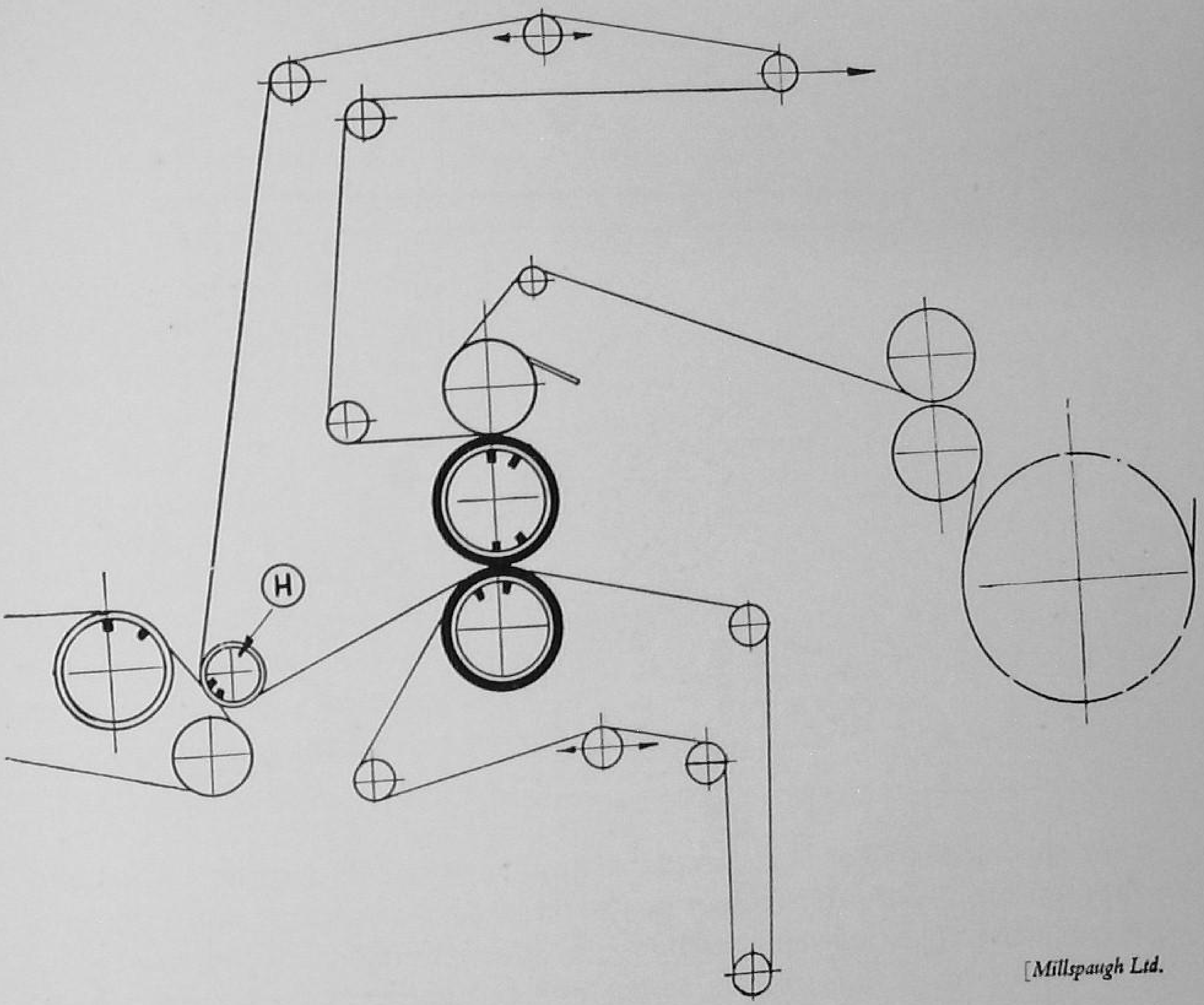


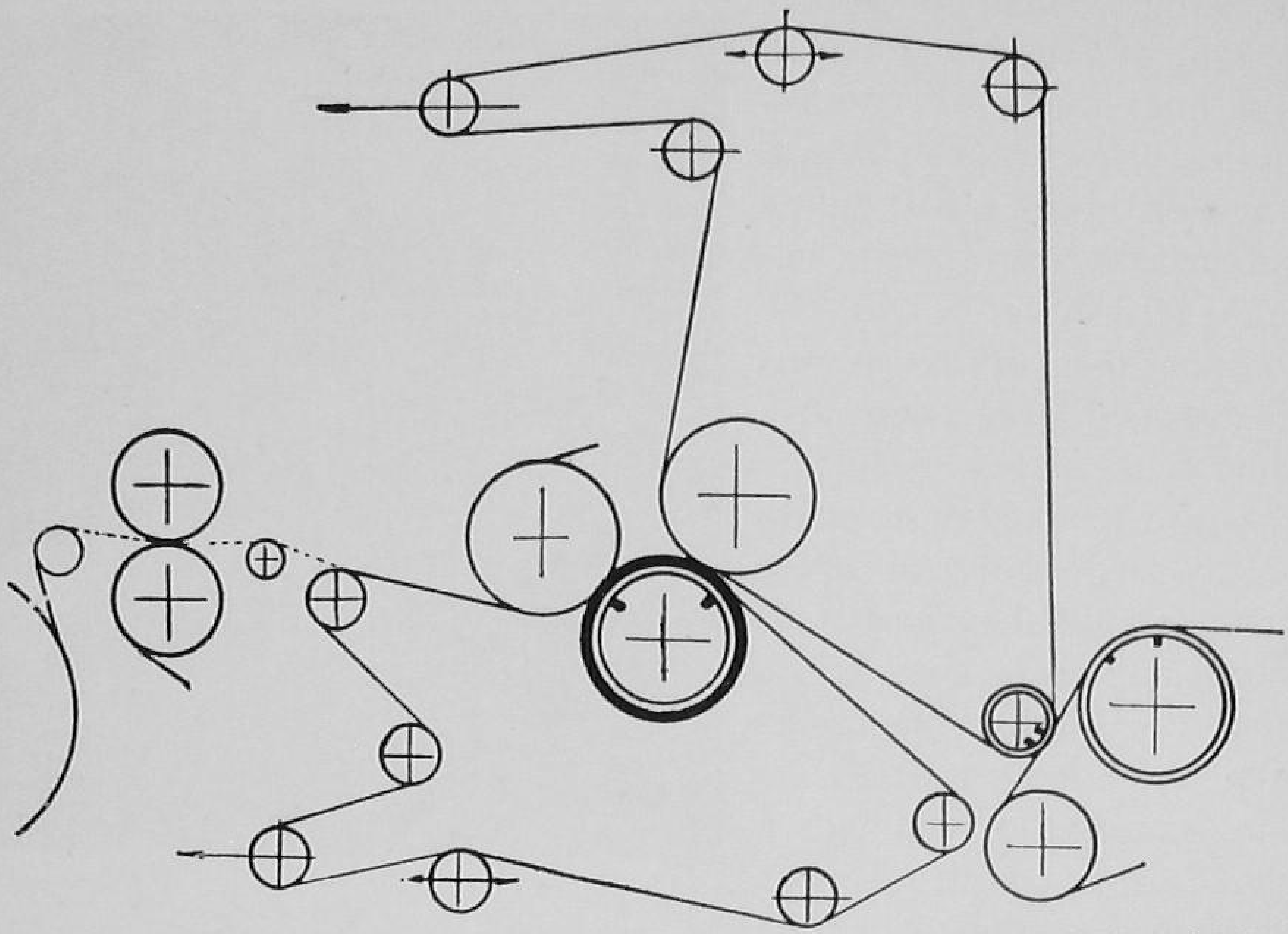
FIG. 134C.—ALTERNATIVE DESIGN TO FIG. 134A.

The sheet is taken off the top roll in the manner usually adopted with the reversing presses, and the wire side of the sheet is pressed by the unfelted top press roll. This necessitates an additional suction roll 'H' for transfer, but the bottom press roll has only one suction box in place of the two boxes required on the pick-up stacked press.

Felts are made in a variety of weaves, full particulars of which can always be obtained from the felt-makers, who are always extremely anxious to co-operate and give service to paper-makers.

It goes without saying that the felt should always be run straight; that is, that the coloured mark across the felt should never be allowed to take up a diagonal course, or to lead very much in the middle. Once the felt is pulled out of square its usefulness is definitely interfered with, the meshes of the weave are closed up, and the felt gives different performance across its width. Far too often felts are allowed to run with the weave stretched diagonally,

or with a big lead in the middle, and this is always due to rolls being out of square, or cambers being wrong, and has nothing to do with the felt.



[*Millspaugh Ltd.*

FIG. 135.—DRAWING OF 'SIMPLEX' SUCTION PRESS ARRANGEMENT, SHOWING HOW THE FELTS ARE ARRANGED

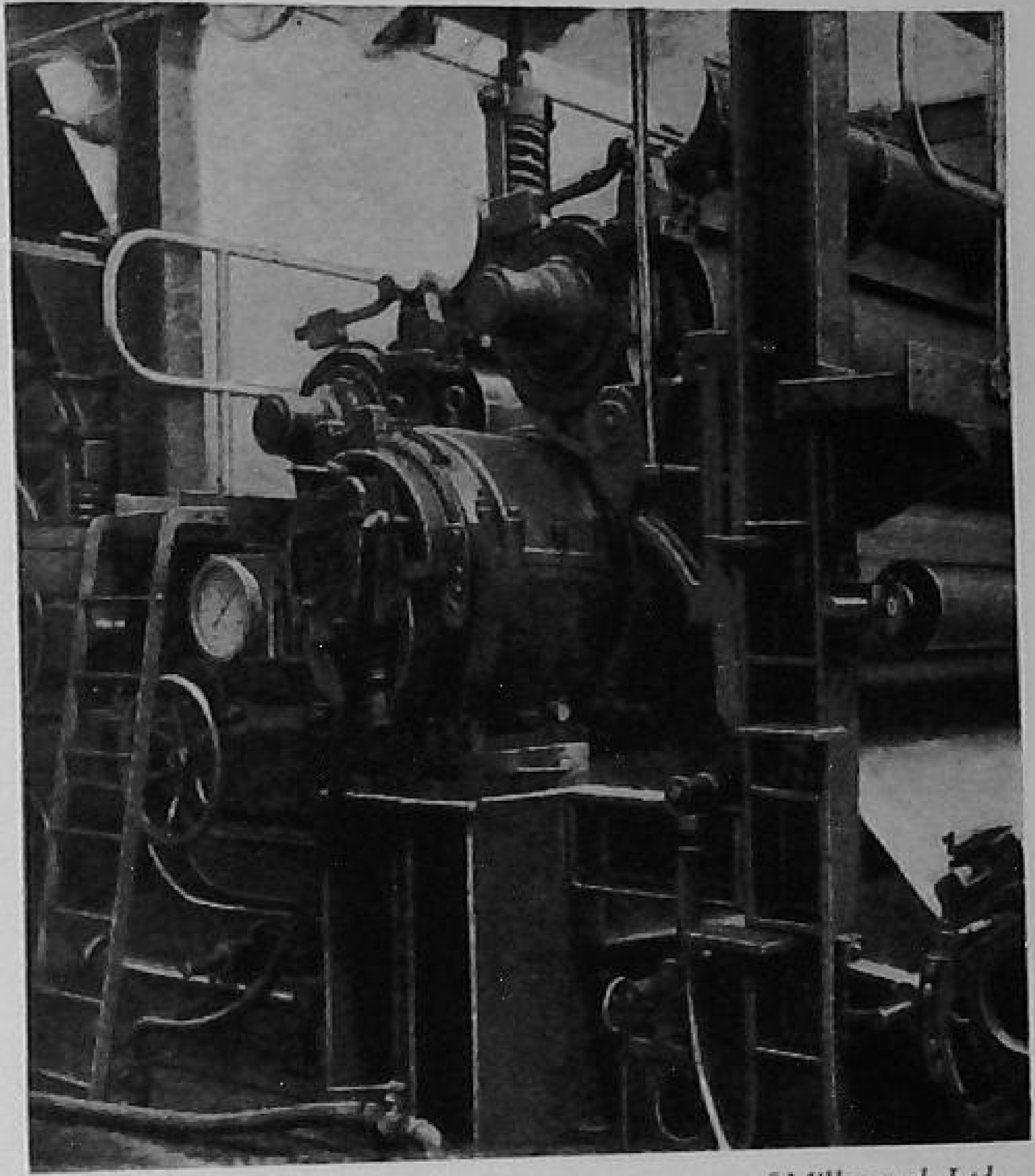
On suction presses it is very often desirable to use 'Duplex' felts, which is simply two or more weaves fastened together with weaving, and different types of felts can be woven together in a 'Duplex' felt. For instance, you may have on the surface a 3 × 1 sateen weave, and on the back side a chain weave fastened to it. These 'Duplex' felts are often made quite heavy, up to as much as 6½ oz. per square foot.

Wet, or Press, Felts.—These felts are invariably made from wool, but wool, by its very nature, is not a soaker-up of water—in fact, it is water repellent—and it takes a good long time before it becomes properly wet. This fact is not generally realized in paper-mills, where the wet felt is expected to soak up water, then part with it at the presses. In point of fact the main function of a press felt is to support the web and to provide sufficient cushioning to prevent crushing of the paper at the pressure necessary to give efficient water removal at the presses. The water is not so much soaked up by the felt as forced through it by the pressure exerted between the rolls.

Where the web and felt enter the nip of the press rolls the water is forced diagonally backwards and downwards through the felt, but in the case of

suction presses the water passes down through the felt at a steeper angle. The ease with which this occurs depends mainly on the size of the pores in the felt. Other things, such as weave and weight of felt, being equal, a felt of finer make will be less porous than one of coarser weave.

In view of this, it is bad policy to use a special extra superfine felt where a special superfine could be used without marking the paper. Another reason for not using extra superfine felts is that their fine pores become blocked more easily than do the larger pores in superfine felts, so that they lose their porosity and become dirty more quickly. For a felt to retain its porosity for as long a period as possible, it must be run with a straight seam, and with no more tension than is necessary to give a good drive without flapping. The felt should clear the pond of water at the nip, and when washing felts off the machine, excessive mechanical working, high temperatures and strong soda ash should be avoided.



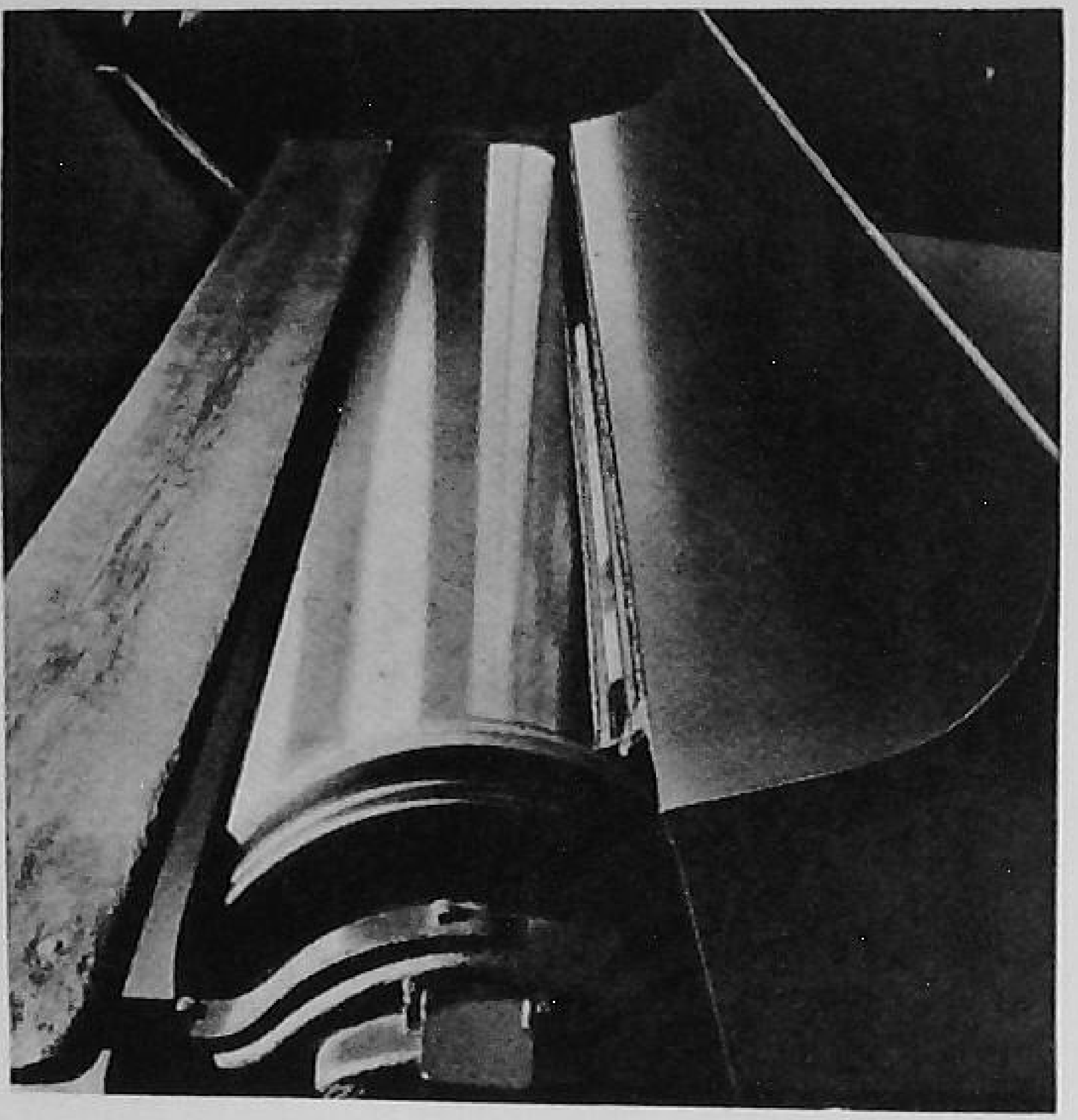
[*Millspaugh Ltd.*

Fig. 136.—Simplex Suction Press, with Millspaugh Suction Roll and Two Press Rolls

This is a very compact arrangement.

It is interesting to note that with a felt that runs, say, for 5 weeks, the moisture contained in the web is about 68 per cent when the felt starts up, this drops week by week until about half-way through the life of the felt the moisture is 64 per cent; and by the end of its life it is down as low as 61 per cent or even less. This shows that as the cushioning effect becomes less pronounced, the felt loses wool and becomes more porous, and allows more water to pass through the weave. The pressure required at the nip is much greater when the felt is new, but it is not generally realized that this pressure, which may be necessary when the felt is started up, should gradually be reduced during the life of the felt, in order to try to maintain an average water removal to, say, 63 or 64 per cent, rather than to keep up the pressure and get the water removal down to 61 per cent. If judgment is used in reducing the pressure during the life of the felt, it will be found that the felt will last possibly another 2 weeks, while giving a good average water removal at the press, and much less chance of marking the paper with the felt weave.

Generally, wet and also dry felts are run far too tight, and it is difficult to know what advantage machinemen think they get from this practice.



[Vickerys, Ltd.

Fig. 136a.—Application of Vickery Doctor to Press Roll

Consequently, the felt will get 'dirty' in a shorter time and require more drastic cleaning. In this case we must reckon the life of the felt on the *quantity of water extracted* as well as on the weight of paper made and the time run. Conversely, with free beaten stuff and a heavier substance that can be well couched, we may easily make ten times the weight of paper without being checked by felt-crushing. Then there is the question of felt-cleaning. The simplest plan is to run a felt until it gets dirty and replace it with a clean one. The felt is then washed on a felt-washer and put back again in turn. The chief objection to this system is the waste of time changing felts. Another plan is to shut the machine and clean the felt without taking it off. This also is time-wasting and really only saves labour in changing felts, since this latter operation could be done almost as quickly as washing on the machine.

Felt-washers operating on the machine as the paper is being made offer a solution of the problem, but are open to the objection that the continual washing wears out the felt as much or more than the legitimate work does. The usual felt-washing apparatus on the machine consists of a series of sprays impinging on both sides of the felt, a pair of rubber-covered rolls to press out the dirty water and a small suction box to dry the felt again ready for the paper.

The Vickery felt conditioner (Fig. 138) is the best attempt to solve the felt-washing problem, and is now in general use. It may be made very drastic in its action and requires skilful and careful manipulation, since, of course, any means of raising the nap and cleaning it by suction is bound to be more or less destructive.

The Vickery Adjustable Friction Type Felt Conditioner.—This is an improved type which has recently been introduced, and whereas in the case of the standard conditioning unit the felt is drawn across the fixed top of the

increase of efficiency and an increased felt life averaging up to as much as 50 per cent.

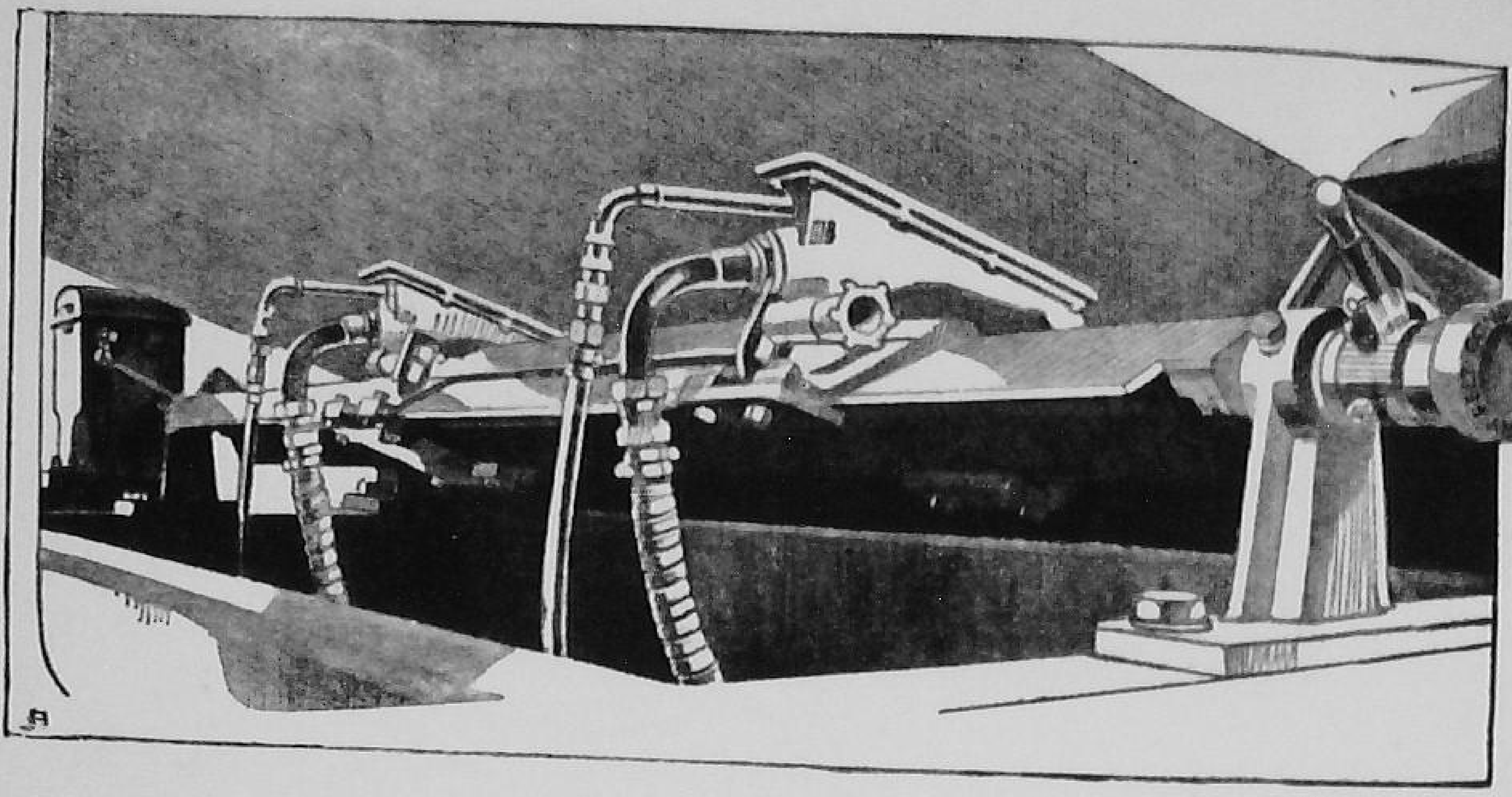
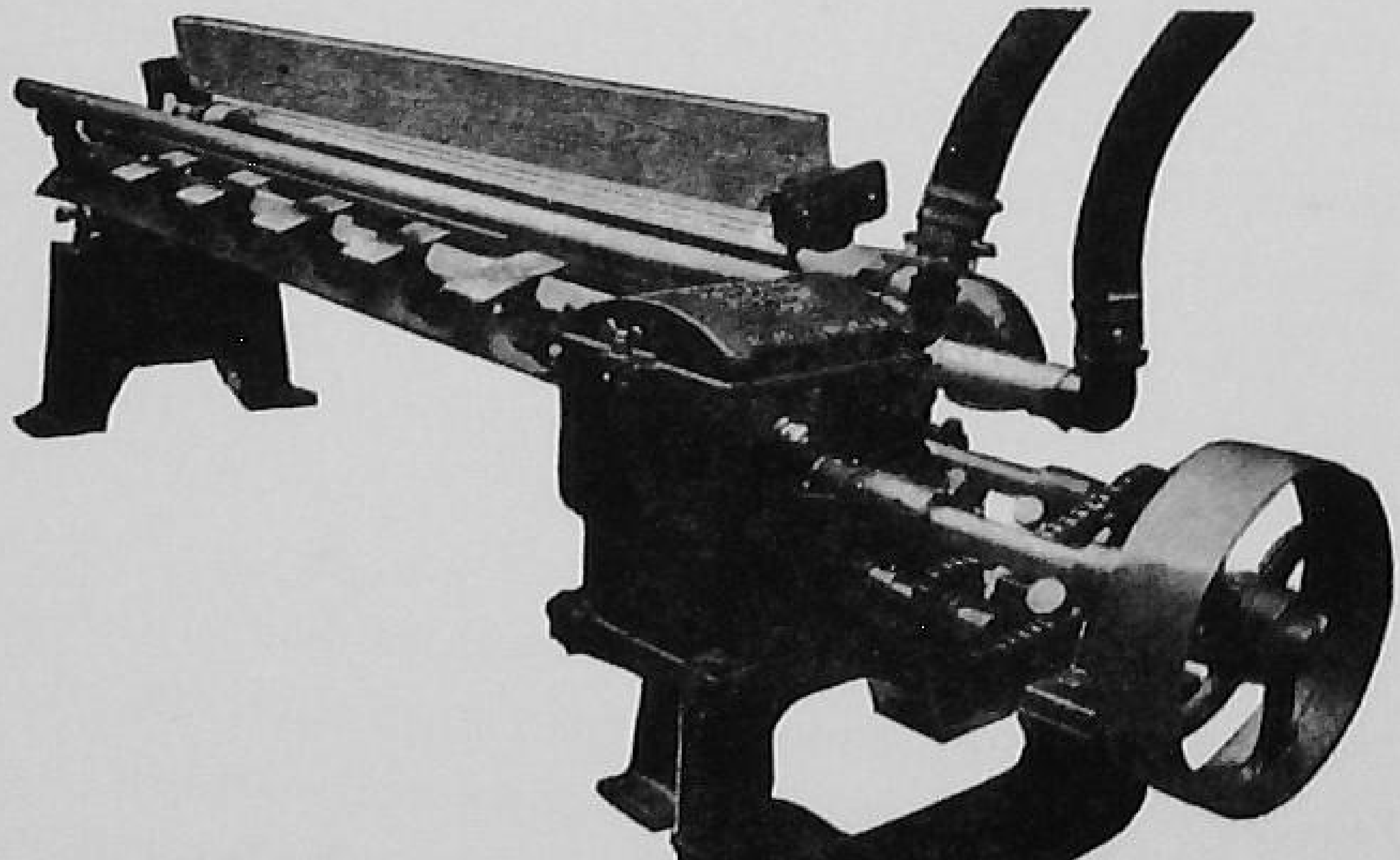


FIG. 138.—VICKERY FELT CONDITIONER WITH TWO SHOES [Vickerys Ltd.

The suction roll is now quite commonly used as a wet-felt cleaning device. Usually it is made smaller in diameter than the suction press roll. To get the best results the wet felt should be carried well round the roll,

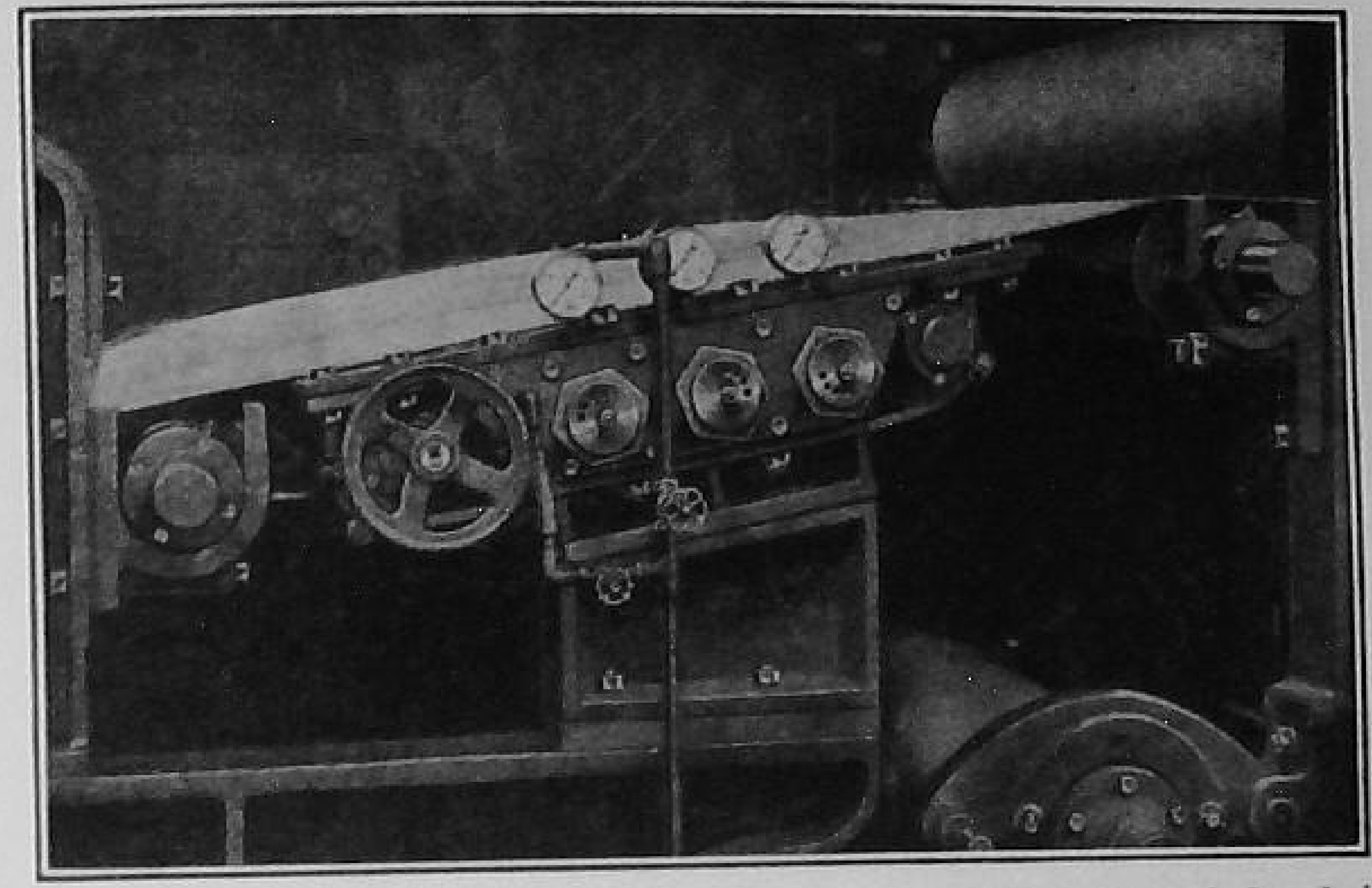


[Vickerys Ltd.

FIG. 139.—THE VICKERY ADJUSTABLE FRICTION TYPE FELT CONDITIONER

and there should be a strong spray of clean water directed on to the felt immediately before it goes to the roll. A very high vacuum is required in

order to dry the felt sufficiently to enable it to take up moisture from the paper when it returns to the press. The chief advantage of this type of cleaner



[W. P. Evans & Son, Ltd.

FIG. 140.—THE EVANS ROTA BELT, WITH THREE SUCTION BOXES, FITTED BENEATH A WET FELT

over the travelling type is that it leaves the felt in the same condition right across the machine.

The Evans Rota Belt type of suction box (Figs. 140 and 141) was originally introduced to take the place of the fixed-top suction boxes under machine wires, but it did not meet with very great success in the early days.

It was then developed for use under wet felts, in which position it has been used with success for drying the wet felt, preventing blowing and generally improving the performance of the press rolls, besides increasing the life of the wet felt.

It has been considerably improved lately, and is now being used with success in place of the fixed-top suction boxes under the machine wire.

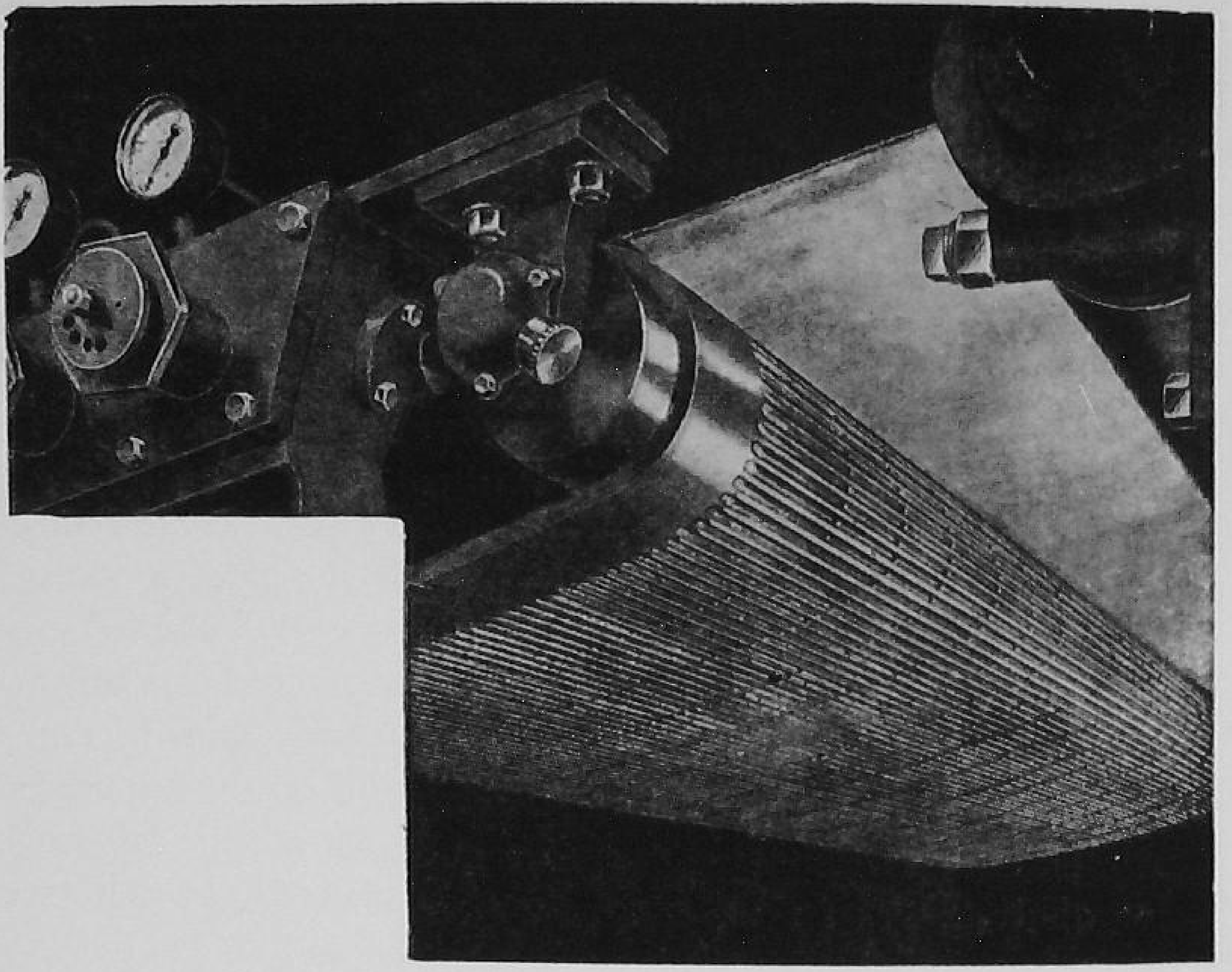
It consists of suction boxes, usually in sets of three, each of which can be individually controlled. Over these a grooved and perforated endless rubber belt passes, driven through friction with the under side of the wire.

The vacuum in the boxes draws water through the belt, and delivers it to the back-water system in exactly the same way as the ordinary suction box.

The chief difference between an ordinary suction box and an Evans Rota Belt lies in the fact that the wire, instead of having to be dragged over hard wooden or metal box tops, passes over the soft rubber band, which is moving at the same speed, and therefore there is a tremendous saving in the friction and consequent wear on the under side of the wire.

The advantages of this will be quite obvious, and it is this saving in

friction which was the chief reason for the introduction of the belt in the first place.



[*W. P. Evans & Sons Ltd.*

Fig. 141.—The Evans Rota Belt fitted under a Wet Felt. The Fluted and Perforated Revolving Rubber Belt is clearly shown; also the Vacuum Gauges to the Suction Boxes

It seems that this belt will now stand up well to the severe conditions of modern paper-machines, and that it may soon have universal application both on felts and wires.

When passing through the first press, the paper, being very moist, takes the impression of the cross-meshes of the felt fabric. In Drawing Cartridge this is called the 'tooth' and is a distinctive feature required and expected by artists and draughtsmen. Coarse mesh felts, specially made for the production of varieties of tooth, may be obtained from felt-makers, and this paper is made in imitation of 'hand-made drawing'. For 'fine' papers, such as writings, banks, ledgers, etc., and body paper for coating and printing, the felt marking is very undesirable, as it prevents a close finish being obtained. The second press is designed chiefly for eliminating felt and wire marks. For this reason the rolls run in the reverse direction to the first press, and the paper is reversed, so that the under side, which is impressed by the wire and felt, is made to come in contact with the top roll of the second press. This has

the effect of greatly reducing this fault, and as the second press is seldom pressed hard, the paper is made more equal-sided for the reception of finish.

Second press felts are seldom washed as they run, but are kept in condition by washing with the force jet at every opportunity, or changed for washing on the felt washer. Although the second press does not often cause crushing when the felt is dirty to the same extent as the first press, the felt must be kept in very good condition. When it becomes the least bit clogged up, it affects the drying of the paper, and is one of the chief causes of 'cockles' and other drying troubles.

When a new felt is put on a machine it requires to be thoroughly wetted with cold water, in order to shrink it to its running tension. If this is not done, it will begin to tighten up soon after the wet paper is run over it.

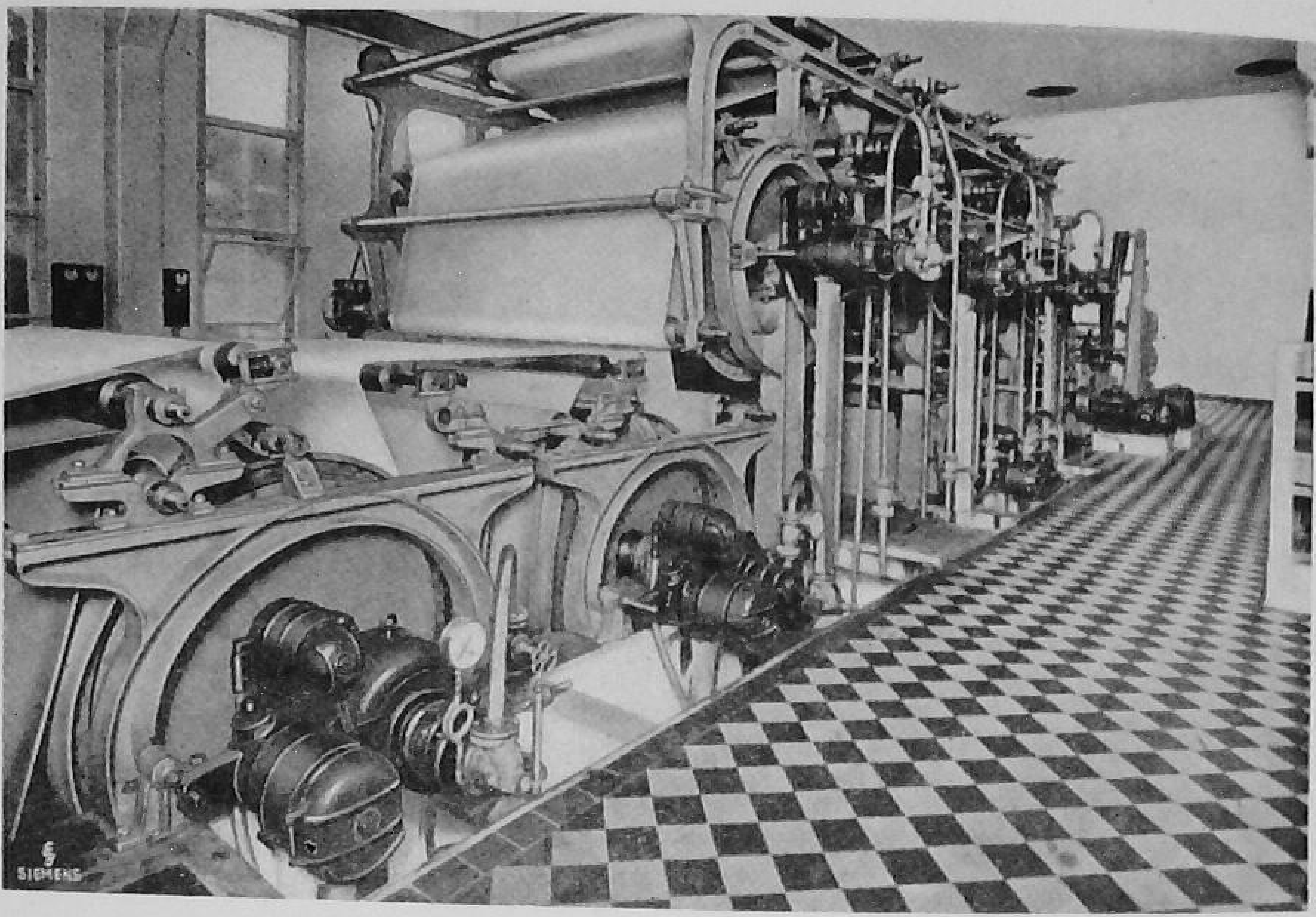
The tension has to be regulated to give the greatest porosity to the felt. If it is too tight it may run into wrinkles, and be less porous owing to the meshes being pulled together. If too slack the meshes will not be opened up and the felt will very quickly become dirty. The coloured line or lines must be kept straight across the machine for the same reason, and the nap should be in the running direction, both on the machine and on the felt washer. All rolls require to be true and perfectly parallel, as a felt is very difficult to run if any one is not correct. Spiral felt rolls help to keep the felt free from wrinkles and the meshes open.

Although it is very desirable to run felts as long as possible, it should always be borne in mind that it is far cheaper to dry paper by the press rolls and felts than by steam in the drying cylinders.

Apart from the loss through breaks and bruised sheets, caused by trying to get an additional week or two out of a worn felt, the addition to the coal bill will be very great, but this is unfortunately very often lost sight of, or it may even be entirely overlooked. The use of felt rolls covered with vulcanite is recommended, as the surface of the vulcanite is 'kind' to the felt, and gives it a longer life.

The Drying Cylinders (Fig. 142).—Having pressed as much water out of the sheet as possible, there is still anything from 64 to 72 per cent of water to get rid of. (See Appendix.) This is accomplished by running the paper over steam-heated cylinders, on to which it is pressed by dry felts. The cylinders are of cast iron with highly polished surfaces and may be from 3 feet (on old machines) to 6 feet in diameter. Steam is admitted to the cylinders by various types of pipes and glands. The most modern comprises the inlet pipe and the condensed steam pipe, or outlet pipe, arranged to enter the cylinder together through the hollow journal at the back side, so as to avoid having a pipe at the front side. This gives more freedom in leading the

paper through and in putting on new felts. Formerly the inlet pipe entered at the front side and the outlet pipe at the back.



[Siemens-Schuckert (Great Britain) Ltd.

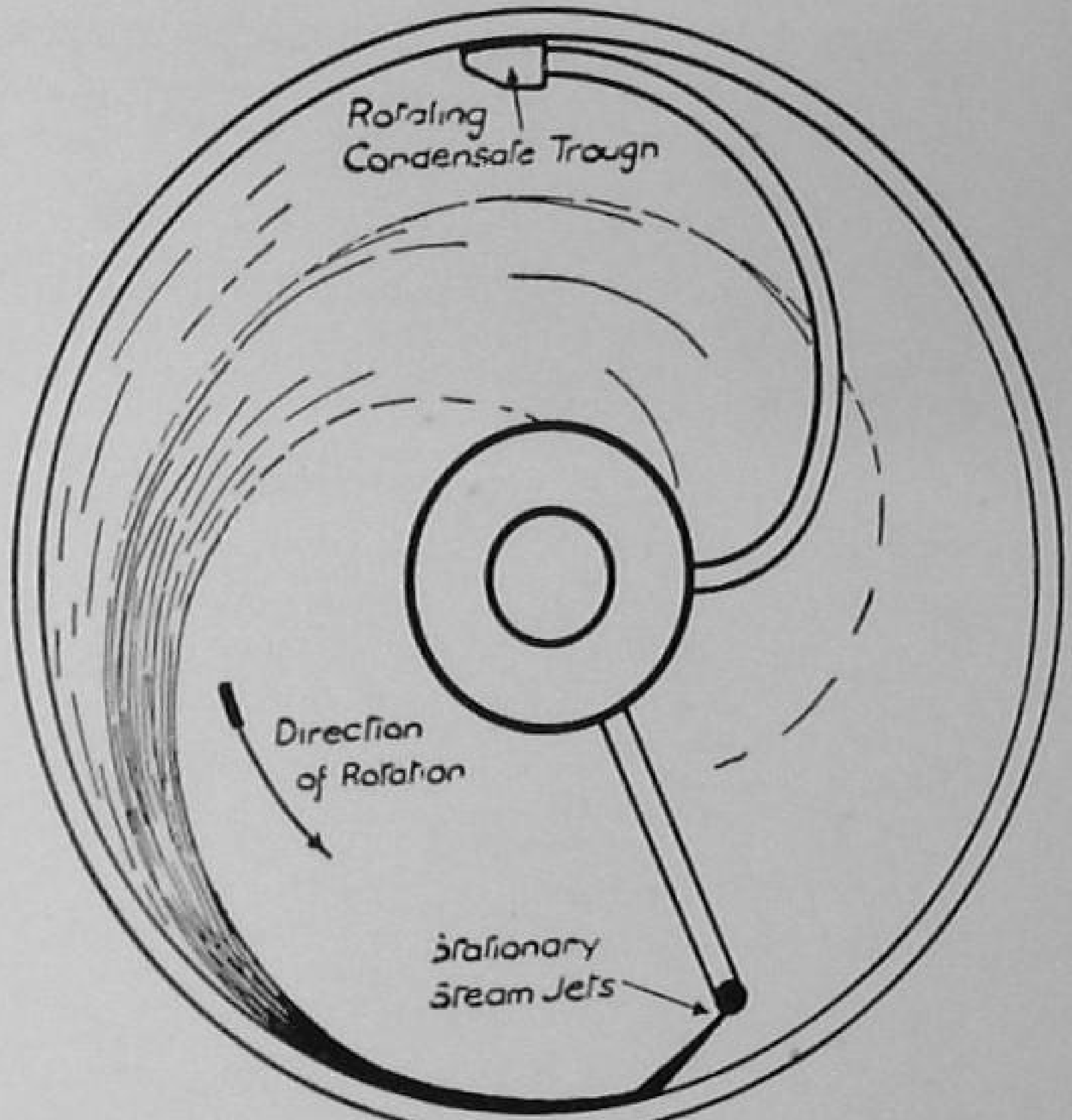
FIG. 142.—ARRANGEMENT OF DRYING CYLINDERS ON A MACHINE MAKING FINE PAPERS
Each cylinder is driven by a separate motor.

Inside the cylinder it is necessary to have some arrangement for getting rid of the water formed by the condensation of the steam. This takes the form of a bucket or chute attached to the end of the cylinder, which scoops up the water and raises it to the centre level, when it runs away through the outlet pipe. A siphon pipe is often used, the outlet pipe being carried to the bottom of the cylinder.

The pressure of the steam forces the water up and out. In the case of cylinders 5 feet in diameter, at a speed of 490 feet per minute, centrifugal force carries the water round the cylinder wall, and both these types become inoperative. Each cylinder should have a separate steam trap, to prevent loss of steam by the steam blowing straight out through the outlet pipe. The simplest steam trap is similar to a water cistern. A floating ball opens and closes a valve in accordance with the quantity of water coming through the pipe. A great many varieties of steam traps have been put into use of late years, but they all work on much the same principle, and, unless kept in good order and regularly cleaned out, are more often than not steam wasters.

Steam and water nozzles without packing are now in general use. The principal feature of these nozzles is the total absence of packing, all the joints being carefully machined, and there is an ingenious system of lubrication by which these joints are kept covered with a thin film of oil, which reduces the friction to a minimum and keeps them both steam- and water-tight (Figs. 144, 144A, 144B).

There are special patterns for drying cylinders, machine and super-calenders, M.G. cylinders and boilers, and they are made for functioning with either water lifters or siphons.



[Bentley & Jackson Ltd.

Fig. 143.—Diagram of Steam in the Drying Cylinder, and Condensate Collecting Trough

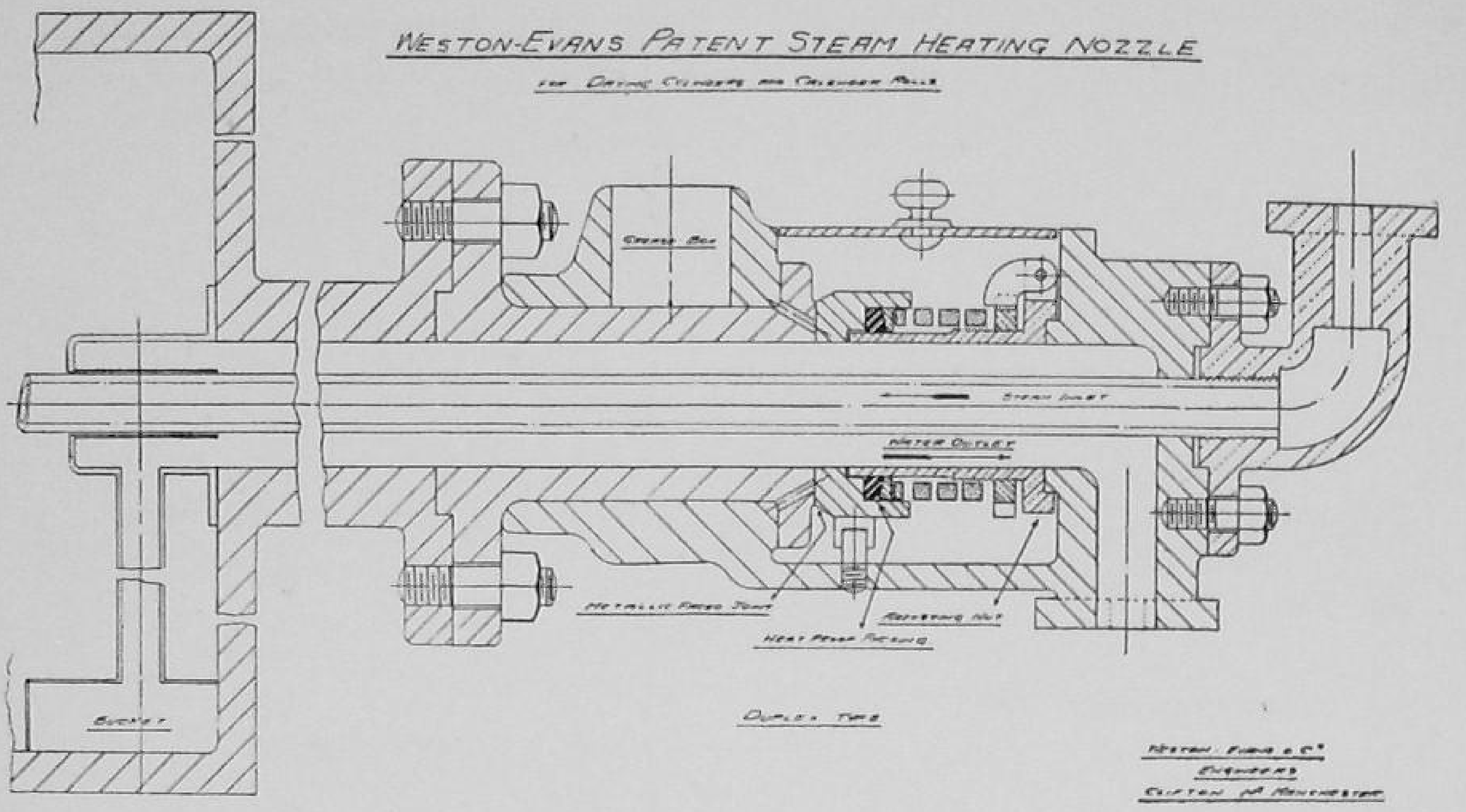
On a machine where the cylinders are few and constantly in use, the outlet pipes may all be connected to one large pipe and one long steam trap. But the objection to this is that the steam blows back and overheats those cylinders that are not required to be very hot, as it is not advisable to have stop valves on the outlet pipes.

Steam Circulation Plants.—The old method of trapping the steam from each cylinder or section of cylinders has now almost entirely given way to a new method of steam circulation. Of the many systems in use two are described, the R.E.C. steam circulation system and the Holmes and Kingcome. The principle of the R.E.C. is that it injects steam into the cylinder, traps that steam when it leaves the cylinder, separates it from the water and reinjects the uncondensed steam again into the cylinder, thus ensuring that all the latent heat of the steam is made use of in heating the cylinder, and until condensed water passes away through the trap to be returned to the hot well.

Very large savings in coal have been effected in many mills by the introduction of this system, together with vastly improved drying on the paper-machines.

The R.E.C. Three-Stage Steam Circulation Heating System.—The simple method of heating cylinders by blowing in steam, and after it has passed on

some of its heat, exhausting the condensed steam through a steam trap, has two disadvantages: first, rather a long time is required in which to drive out

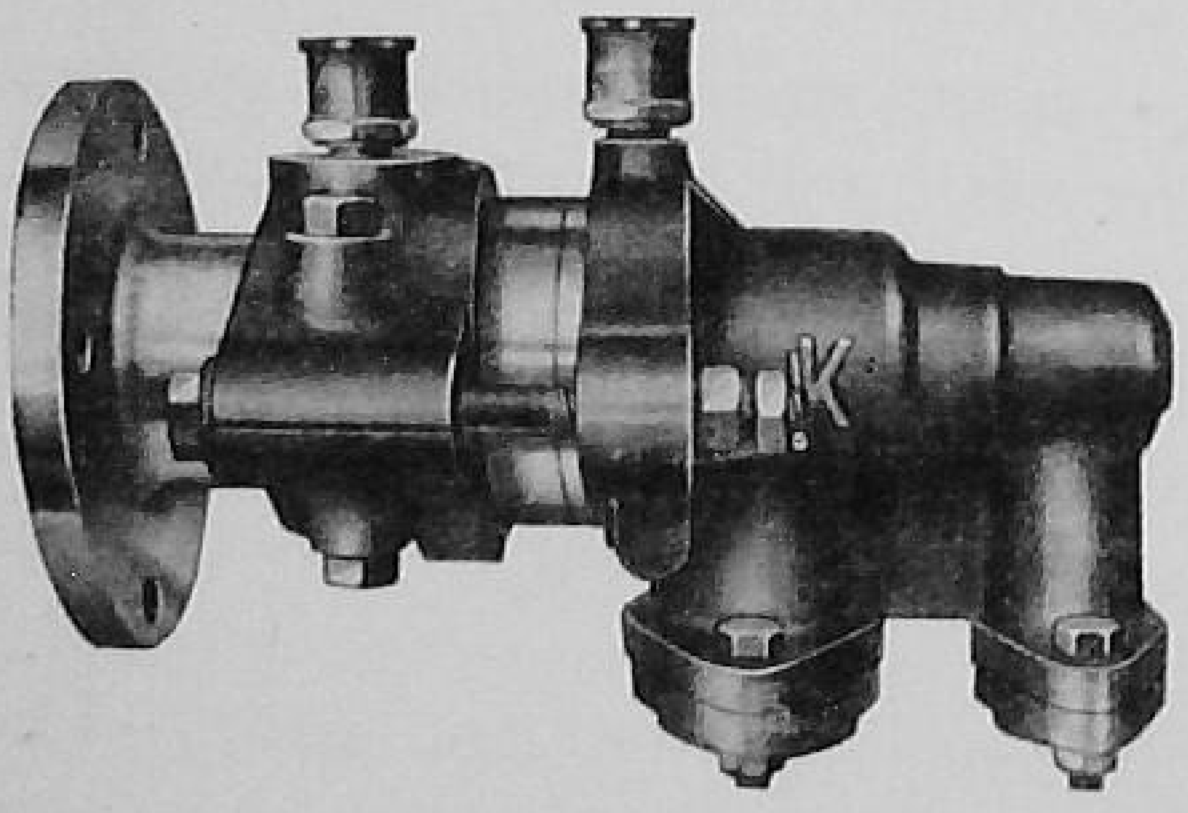


[*Weston-Evans & Co.*

FIG. 144.—PATENT STEAM INLET AND WATER OUTLET NOZZLE FOR CYLINDER AND CALENDERS

This nozzle remains perfectly steam- and water-tight at all pressures up to 260 lb. per square inch, and is suitable for either syphon or bucket condensate ejection and for the straight-in feed on calender rolls. It is also made in single form where the steam is fed in at one end and the water ejected at the other.

the cold air from the cylinder to be heated; and, second, there is much inevitable wastage of steam through the trap. The original R.E.C. circulation system was designed to eliminate these faults. Provision of sufficient cocks in the system and skilful design of piping enabled the air to be rapidly released from the cylinder to be heated, but the main feature of the system lay in economy of steam consumption. This was effected by separation of steam from the exhaust from the cylinder, and the continued use of this steam until it had parted with all its available heat. Direct steam was not blown straight into the cylinder, but was passed through an ejector, which drew the exhaust steam from the trap, so using a mixture of fresh and reduced pressure steam for heating. Steam entering a cylinder was constantly being drawn out and put back again, through the ejector, until it had parted with all its available heat and become condensed. The two essential features



[*Edward Kempster & Sons, Ltd.*

FIG. 144A.—KEMPSTER'S PACKINGLESS COMBINED NOZZLE

of the system were the steam trap, which incorporated a separation chamber for the steam, and the ejector, which relied upon steam for its operation.

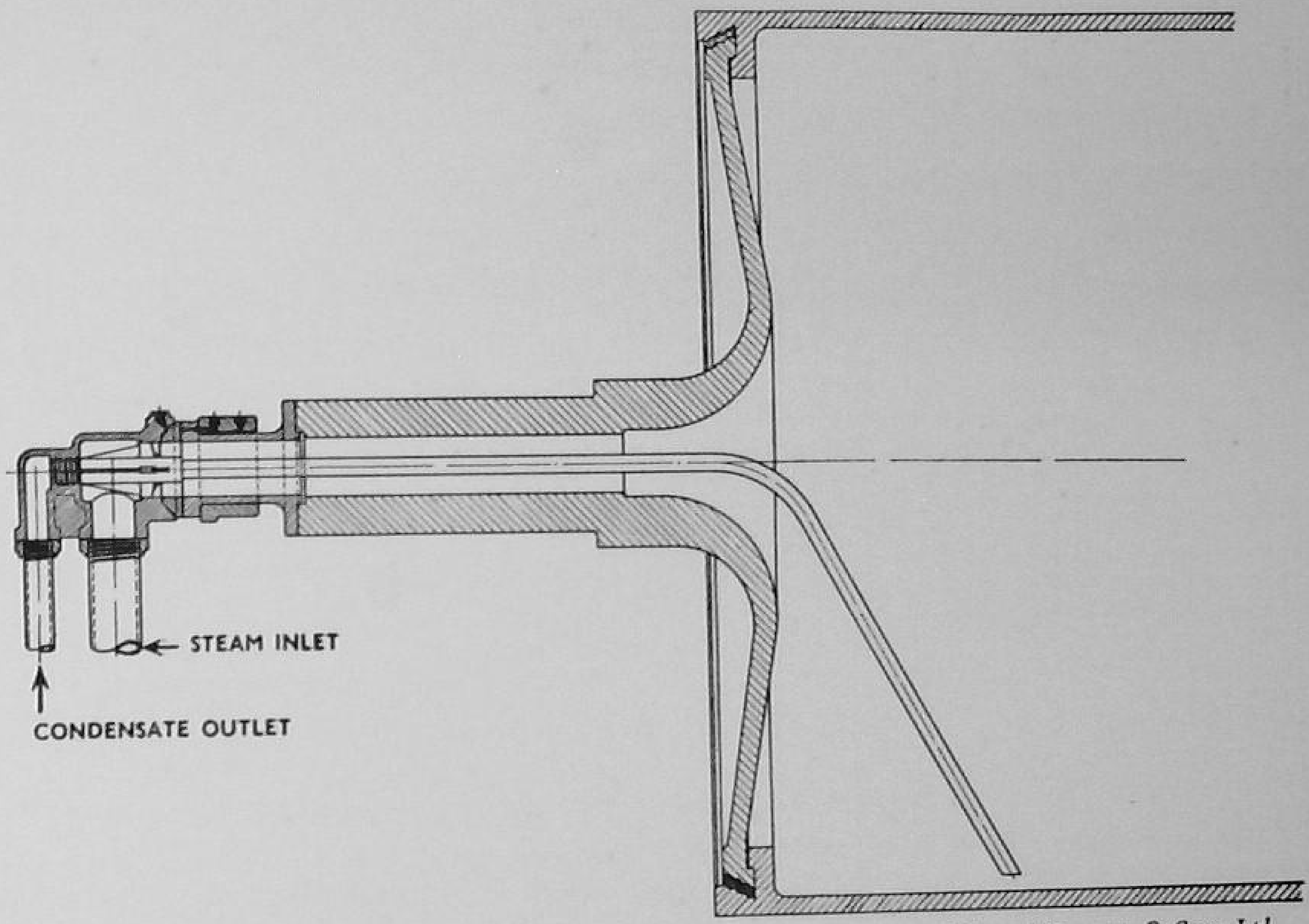
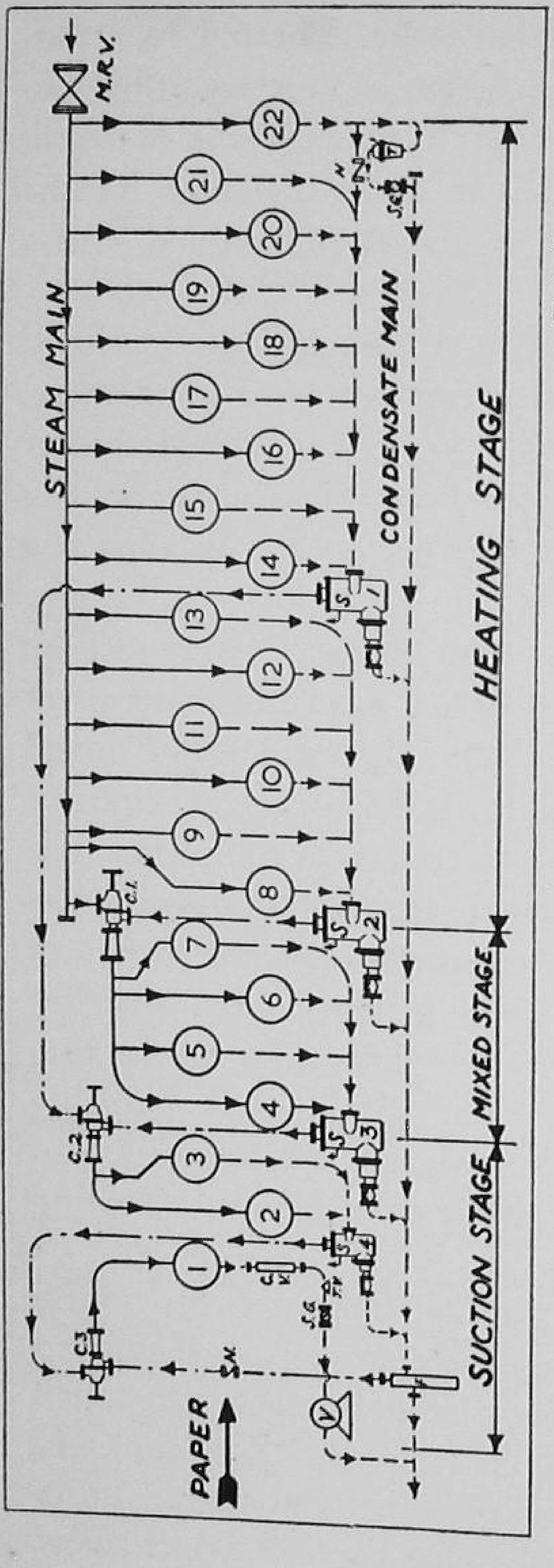


Fig. 144b.—Cross Section of Kempster's Packingless Combined Nozzle for Machine Drying Cylinder

The improved R.E.C. three-stage steam circulation heating system retains these two important features in unchanged form, but uses a different cycle of operation. The extravagant feature of the original system lay in the fact that the same temperature was attainable on all cylinders, and most economical working was effected only when such conditions obtained. When the last cylinders were required very hot and the first cylinders only just warmed, the system suffered by the recirculated steam cooling the direct steam, its original temperature never being fully utilized in the cylinder. In the latest R.E.C. three-stage steam circulation heating system, heating is done in three separate stages, enabling still greater economy to be effected by the more complete use of the heat of the steam.

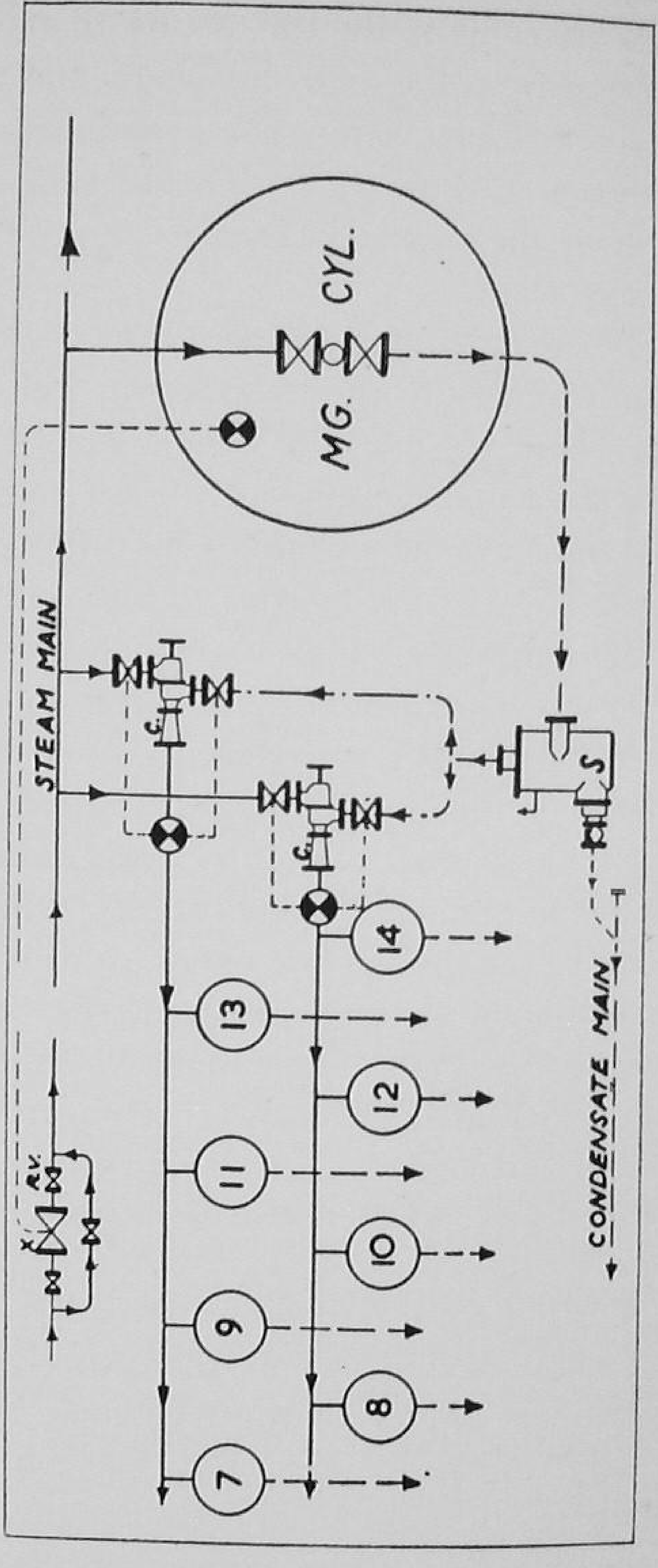
The R.E.C. Velocity Steam Heating System (Figs. 145 and 146).—The drying section of a paper or board machine is usually divided into three stages which are further subdivided into groups of cylinders according to the quantities and types of paper manufactured.

Suction Stage.—In this stage, by low temperature and gradually rising



[Reiss Engineering Co. Ltd.

FIG. 145.—DIAGRAM OF COMPLETE REISS STEAMING SYSTEM FOR PAPER-MACHINE, SHOWING DIRECTION OF STEAM FLOW



[Reiss Engineering Co. Ltd.

FIG. 146.—REISS STEAMING SYSTEM FOR M.G. MACHINE

steam pressure, the warming up of the stuff and initial evaporation of the water takes place. It is for this reason that the suction stage is heated by steam absorbed from the following stages and the flash steam completely utilized in the first cylinder before the pressureless condensate is taken to the hot-well, as shown in Fig. 145. The suction stage serves as a condenser for the whole of the steam used on the machine, and is, therefore, coupled with a vacuum plant.

Where air heaters are used for hot air supply on drying cylinders, exhaust steam taken from the cylinders as well as flash steam from the condensate, and, where possible, hot condensate itself is used for feeding the air heater coils, a vacuum pump only being necessary for returning the condensate from the air heaters to the collecting tank if the air heaters are installed at a low level.

Mixed Stage.—This is the most important part of the drying section, for in this stage a mixture of direct and exhaust steam drawn from a part of the heating stage is introduced via a steam circulator. By coupling the mixed stage with the heating stage the necessary elasticity for different kinds of paper is obtained. It is, by regulation of the steam circulation apparatus, possible to obtain a gradually rising temperature curve which is, for instance, necessary for thin or fine paper, or to raise the temperature on the surface of the cylinders almost as high as that in the heating stage as required, for instance, by kraft. To obtain this condition the cylinders in the heating stage which are fed by direct steam from the steam main must be perfectly drained and vented. Therefore the majority of the steam subsequently used in the mixed and suction stages is passed through the cylinders of the heating stage.

Further advancements achieved have been the complete automatic control of a whole drying section, the control being operated from a panel situated on the service side of the machine. This control can better be explained by referring to diagram Fig. 145 on which master valve 'X' completely dominates throughout the system the relative pressures and temperatures of the cylinders. Circulators 'C' are also provided with controls, which allow the maintenance of a differential pressure between themselves and between them and the master valve 'X'. Alterations to the differential pressures are easily adjusted on the control panel.

A warming-up circuit can also be incorporated in the automatic controlling equipment by the interposing of a specially timed self-opening valve, 'R.V.,'

controllable from the same panel. This valve, whilst opening, passes gradually increasing quantities of steam through the system, allowing the cylinders to heat up evenly and at the same time gradually displacing quantities of stagnant condensate and air which have formed in the drying cylinders during the shut down and cooling of the machine.

When this valve, 'R.V.,' has opened sufficiently, the main controlling valve 'X' automatically comes into operation, thus obviating the risk of water hammer.

Equipment of the Stages.—Each group of cylinders in the various stages is equipped with a steam and condensate separator, into which the exhaust steam and condensate from the drying cylinders are discharged and separated. The separators are supplied with automatic thermostatic air escape valves, allowing only dry steam, free from air, to be supplied to the following stages.

A swirling motion produces an efficient and complete separation of the exhaust steam and condensate. A drain cock is fitted at the base of each separator giving means for removing sludge and foreign matter which may collect in the bottom of the apparatus.

The groups of the mixed and suction stages are additionally equipped with combined steam circulation apparatus. These are so designed that they can work either as injectors or, if the difference of the steam pressure is very low, as mixing valves.

In the suction stage the steam circulators supply exhaust steam from the mixed stage and make-up steam from the heating stage to their group of cylinders, whilst in the mixed stage they supply exhaust steam from the heating stage to their groups of cylinders with the possibility of adding make-up steam from the steam main.

The steam circulators are capable of dealing with varying quantities of steam to suit the requirements of the smallest and largest board and paper-machines.

The flash steam separator, which is constructed to individual requirements of the plant, releases without any obstruction the flash steam to either the first cylinder or the air heater, completely eliminating the possibility of any back pressure on the condensate main.

The vacuum plant consists of a specially designed cooling vessel and a thermostatic valve which regulates the temperature of the cylinder exhaust to the vacuum pump. This thermostatic valve is also a precautionary measure for the efficient and safe working of the vacuum pump which normally

works with a 5-inch vacuum at the inlet and is driven by a small motor ($\frac{3}{4}$ to 2 h.p.).

Holmes and Kingcome Steaming System (Fig. 147).—This steaming system is based on the well-known principle of increasing the heat transference through any heating surface by increasing the velocity of steam applied to the opposite side of the surface; thus in the case of paper-machines, the faster the steam is passed through the cylinders the more heat is passed through the cylinder walls, consequently giving increased drying power.

The method used to obtain maximum circulation coupled with economy of steam is shown in diagram.

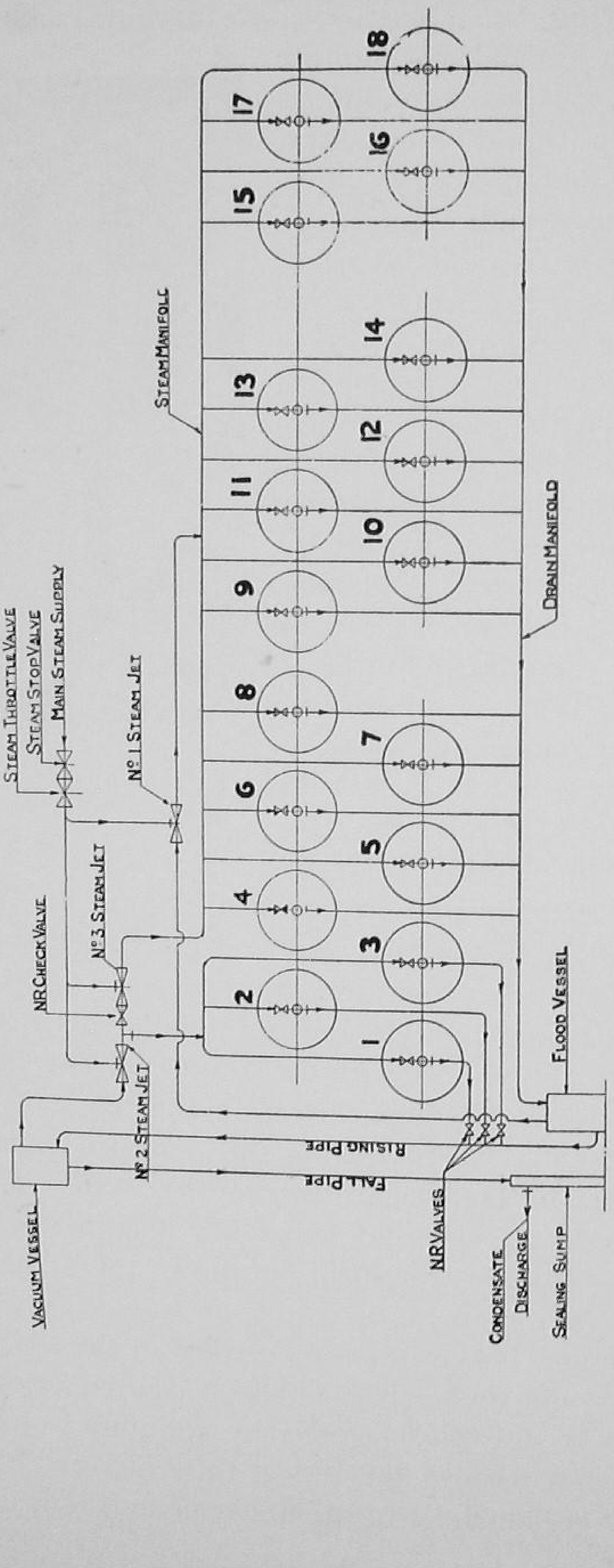
The steam is applied to three jets, the bulk passing through No. 1 jet which feeds all cylinders except the first three. As there are no steam traps or other restrictions in the piping, the steam passes straight through the cylinders and exhaust pipes to the flood vessel, where the condensate is separated from the steam, air and CO_2 escaping to atmosphere from a release valve. The separated steam is sucked off by No. 1 jet and blown through the cylinders again, and the condensate is sucked up into the vacuum vessel by No. 2 jet. As water under vacuum boils at a lower temperature, the condensate boils again in the vacuum vessel and the steam given off is used to feed the first three cylinders, the surplus being boosted up to main manifold pressure by No. 3 jet to be used again.

The resulting condensate left in the vacuum vessel falls down the fall-pipe, which acts as a barometric leg, and trickles out of the sealing sump. As this condensate has been under vacuum, its temperature is consequently very low.

Another valuable addition to this system is the use of an internal stationary steam jet inside the cylinder, which blows steam direct on to the cylinder wall at line pressure. By this method a still greater velocity as well as a drier cylinder is obtained.

All cylinders have to be very carefully balanced. A heavy side will cause a jerky motion, which makes the paper wrinkle or break. They are also graded in size, diminishing towards the dry end to allow for the decreasing shrinkage of the paper.

Besides the cylinders over which the web passes, each dry felt has one or more additional cylinders over which it runs on its return journey, in order to be dried. This is commonly called the 'felt dryer'. The number of cylinders required on a machine depends on a great many things—the length and mesh of the wire, the number of suction boxes, the weight of the couch

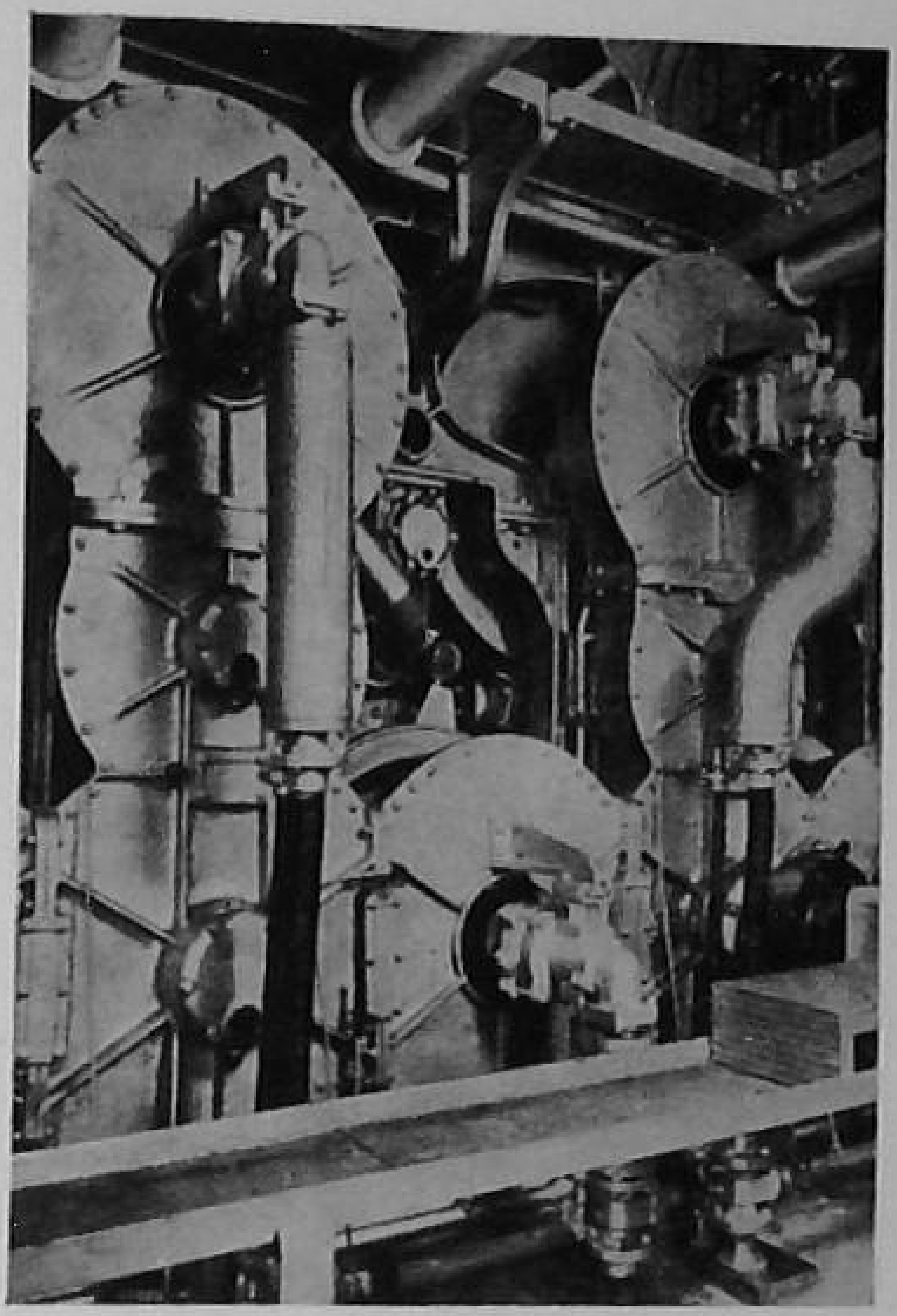


[Holmes & Kingcome

FIG. 147.—THE HOLMES AND KINGCOME STEAMING SYSTEM

and press rolls, the quality and substance of the paper, the speed, the steam pressure used for drying, etc. Obviously for a machine making a wide range of papers it is very difficult to suit the number of cylinders to all these conditions. For some papers eight would be sufficient; for others, five times that number would be wanted. From ten to twenty cylinders on an ordinary Fourdrinier is a fair average.

Felt Dryers.—It is at last being realized that the conditioning and proper drying of dry felts is a very important part of paper drying, and quite recently a very excellent type of felt dryer has been made available. While it has invariably been the case that certain cylinders have been added for the purpose of drying felts, something more was wanted, and the Happer dryer is an excellent solution of this difficulty of keeping dry felts in condition. It consists of a small drying cylinder rather like a suction roll and it is inserted between the sections of dryers in the same way as the felt-drying cylinder or in place of a carrying roll. As the felt passes over it, it is subjected to suction from a vacuum pump, and this draws the moisture away from the felt surface, and so dries the felt and leaves it in a condition to take any further moisture from the paper. This has the double advantage of conditioning the felt and the atmosphere around the dryers at the same time, for this reason: with the ordinary felt-drying cylinder the heat of the cylinder drove the moisture from the felt into the pockets, or under the hood of the dryers, still leaving this moisture to be dealt with by hot air and fans. In the Happer arrangement the water vapour is actually sucked away through the felt and exhausted to atmosphere outside the machine house, an advantage which will be readily appreciated.

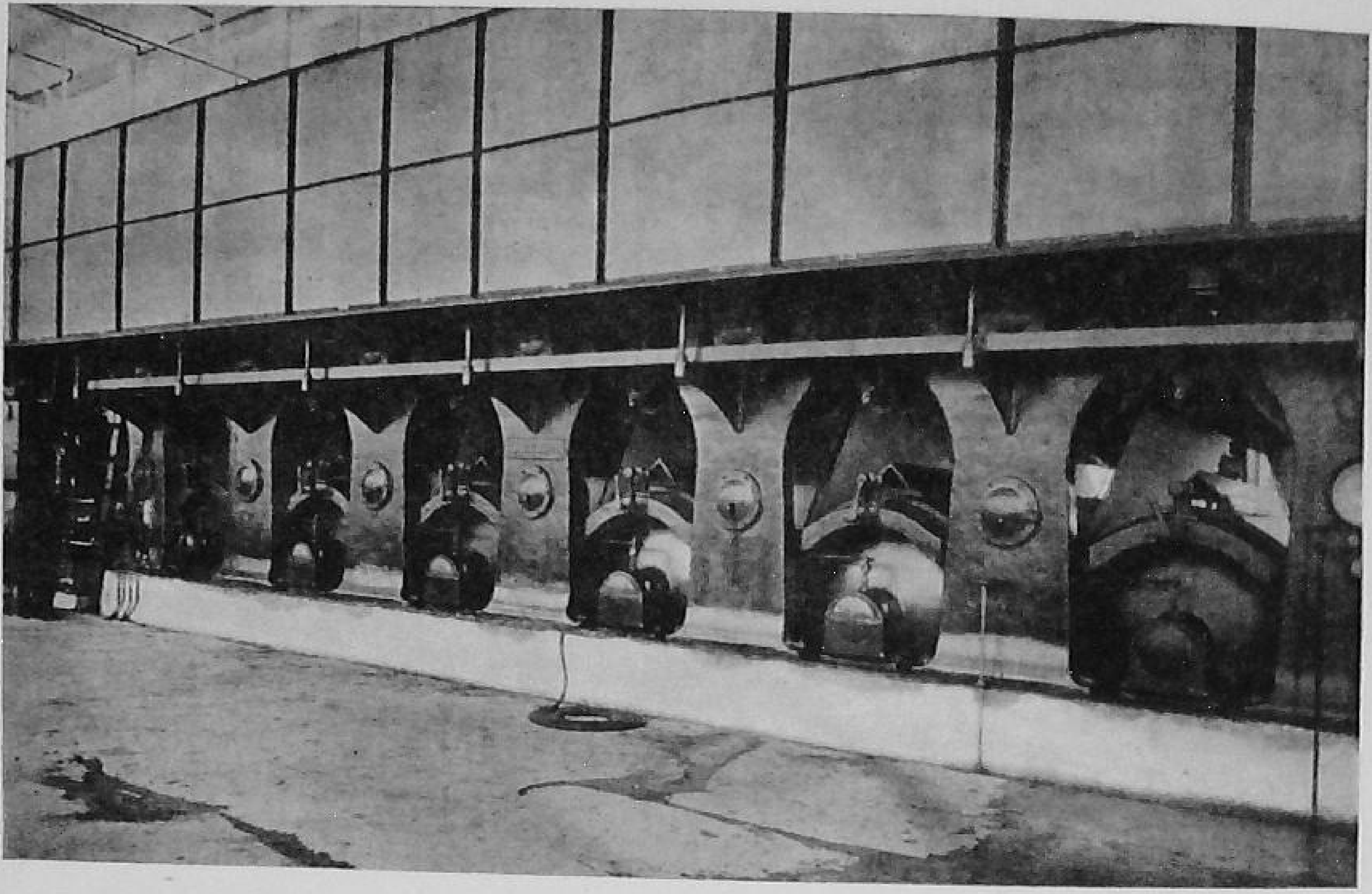


[*Walmsleys (Bury) Ltd.*

FIG. 148.—TOTALLY ENCLOSED DRIVE FOR DRYING CYLINDERS, SHOWING VERY CLEAN AND SAFE DESIGN

Dry Felts.—Dry felts may be of cotton or wool. The latter are most efficient and last longer, but are more expensive in the first place. Cotton felts mark the paper and shed cotton fibres on it after a time, and for this reason may have to be discarded before they are quite worn out. Woollen felts shed a brown dust towards the end of their life, but by the time this takes place they are very much burnt and nearly useless. The cylinders should

never be run when the wet end is shut for washing up or changing. After a few turns to get the felts thoroughly well dried the cylinders should be



[*Black-Clawson-Dilts, Hamilton, Ohio*

FIG. 149.—MODERN FRAMING FOR DRYING CYLINDERS, GIVING EASY ACCESS FOR OPERATIVES, SHOWING HOOD, AND CYLINDER DOCTORS

stopped, and the felts slackened off a little, to release the strain on their fabric caused by their shrinkage on drying. The felt-drying cylinders must have full steam on when the machine is running. This is much more important than is generally recognized. Owing to the blocking up of a steam-pipe leading to the drying cylinder, a woollen felt that would normally have run for six months became rotten and went to pieces in a fortnight. On many machines dry felts are guided by hand, but there is no reason why this should be so, as automatic guides are simple and easy to fit. The lines of a dry felt must be kept straight, otherwise drying will be uneven, owing to the felt being tighter at one side than another. In many cases guide rolls will be found in the wrong positions. To check the felt, the roll has to be altered in such a way as to end the line off the straight. All fast-running machines now have automatic felt guides.

The guide roll should be on a stretch of felt where altering its parallel does not materially alter the tension of the felt. It is bad policy to run a felt too long. A felt may look to be capable of a few weeks' more work, but it may be, and usually is, worn thin in the centre, and this makes drying very difficult.

This will be reflected in unequal finish later on, especially on machine-finished papers, and cockles, etc., on thin papers. Much more steam is required to dry paper if the felts are well worn.

The satisfactory drying of paper on the Fourdrinier machine and the prevention of condensation in the machine house constitute two difficulties which until very recently have been unsurmounted by paper-makers and paper-mill engineers. The extra output required during recent years, in order to keep up with competition from new mills, has often been badly handicapped by lack of sufficient drying power at the machine.

For whereas it has often been found possible to speed up an old machine mechanically without detriment to the paper, it has usually been found that there were not sufficient drying cylinders to dry the paper at a great speed, and, what is more, no room to put in additional cylinders. In one mill at least this trouble was overcome by adding a third tier of cylinders above the existing two. To get over this drying problem the present tendency is to introduce warm air into the machine room and blow it into the 'dead pockets' among the drying cylinders.

Vapour absorption plants are in use in many mills and give very good results, both in increased output and also in the saving of dry felts. They have superseded the earlier method of introducing warm air though ducts under the roof, for while this plan certainly helped very greatly in reducing the condensation of water on the roof and girders, it could not be said to add much to the drying efficiency of the drying cylinders. The system of vapour absorption by hot air both increases the drying power of the machine and at the same time prevents condensation above the machine by absorbing the vapour as it leaves the paper, thus preventing it from ever reaching the roof in a saturated condition.

The vapour is chiefly released in the pockets between the drying cylinders, where there is very little natural movement of air, and fog or steam can nearly always be seen hanging about there. With the Sturtevant and similar systems warm air is introduced into the 'pockets' by means of specially designed perforated pipes. These pipes have perforations which ensure that the air is discharged directly on to the felt, or paper, whilst at the same time surmounting the difficulty of projecting nozzles which interfere with the work of clearing broke and feeding through.

The air is drawn from outside by a centrifugal fan, and is blown through a steam heater. The apparatus may be placed in almost any position in the machine house or even outside it. The heater can be fed entirely by exhaust steam, or may be divided into sections, one using exhaust steam and the other live steam.

The warm air from the heater is distributed throughout the length of the dryer by galvanized sheet steel ducts, which in turn feed the various pipes distributed into the pockets, or above and below the felts of the machine. The drying capacity of the machine can be increased 15 to 25 per cent, with a corresponding increase in possible output. Fog in the machine room and drip from the roof are usually considerably reduced, and there is no need to emphasize the importance of this latter benefit, for it is bound to save many hundreds of pounds a year in breaks and broke, at least in mills where trouble is experienced from roof condensation, besides the great saving in roof maintenance costs.

The length of life of dry felts in one mill we know was increased as much as three times when this system was installed, and the output was at the same time increased by 15 per cent.

There is no doubt that it is a much cheaper and quicker way of adding to the drying power of a machine than by the usually very inconvenient method of installing extra dryers.

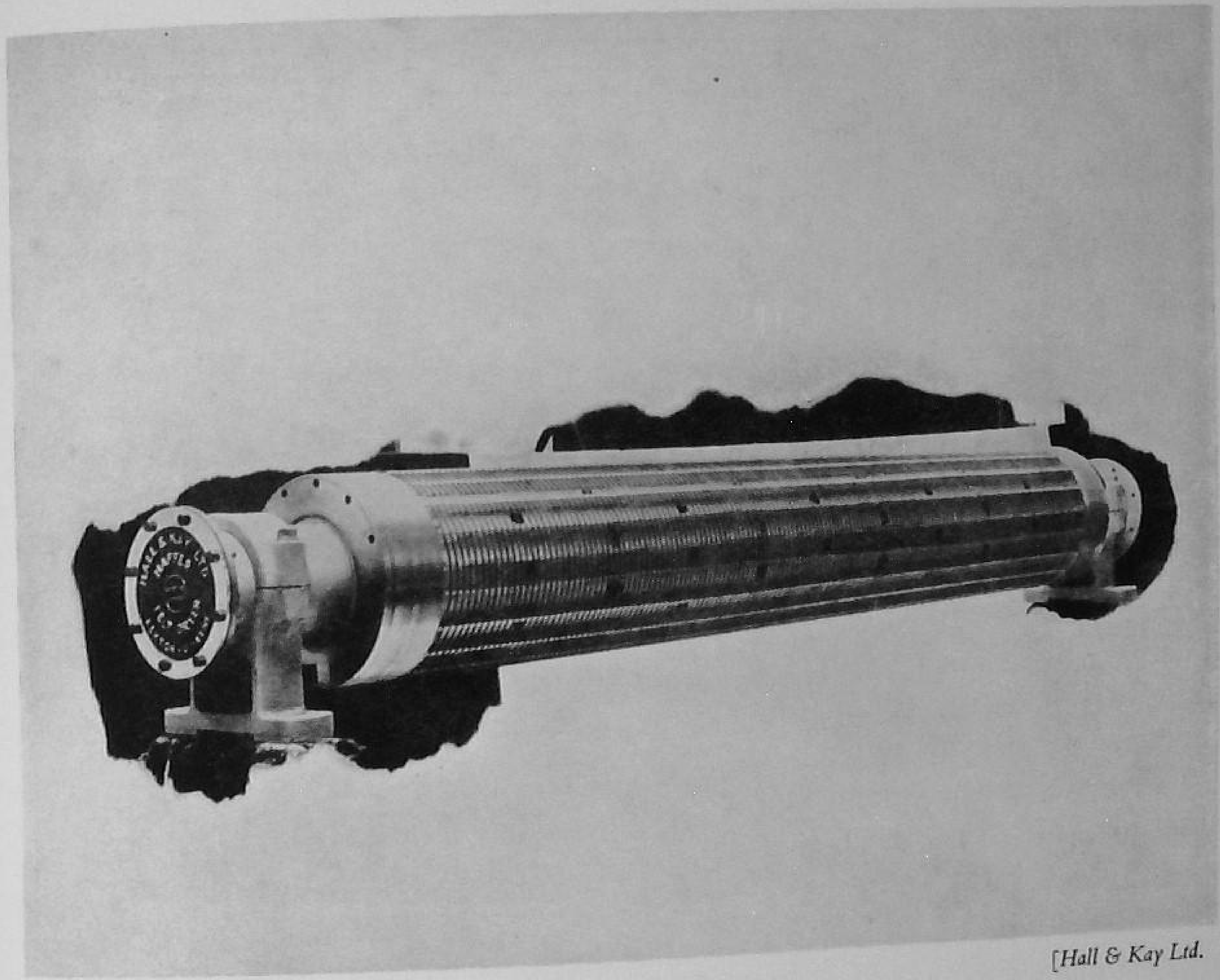
The Happer Patent Felt Drying Roller (Figs. 150 and 151).—An important point to ensure even drying of the paper and freedom from cockles is the keeping of the dry felts evenly and properly dried.

Dry felts absorb a lot of moisture from the paper as it is driven out by the heated cylinders, and they ought to be able to pass it away to the atmosphere continually, in order that the wool may absorb further moisture on the next revolution of the felt.

Originally felts were dried by passing them over separate drying cylinders not in contact with the paper. A further improvement on this was the blowing of hot dry air on to the felt and into the pockets between the cylinders in order that this air might absorb moisture. This air was subsequently drawn away by fans. Both these methods have the defect that only the surfaces of the felts are dried, the moisture remaining in the vicinity of the paper-making machine, and some of it recondensing on to the felts. Also the hot and humid conditions in the machine house, brought about by this method of dealing with the moisture, make the working conditions unpleasant and cause troubles such as condensation on any cold parts of the machine frame and roof and walls of the machine house. This causes damage to steel work, and falling drops of moisture, which are very troublesome when they fall on to the paper-machine.

Several methods have been put forward to tackle this question of the conditioning of dry felts, but the one which seems to be the most successful and which is very satisfactory in use is that known as the 'Happer' patent felt drying roller. These rollers, which are illustrated in Fig. 150, can be put

on in convenient places among the drying cylinders, and their construction is such that, as the felts pass over the roller, the heat and moisture-laden air



[Hall & Kay Ltd.

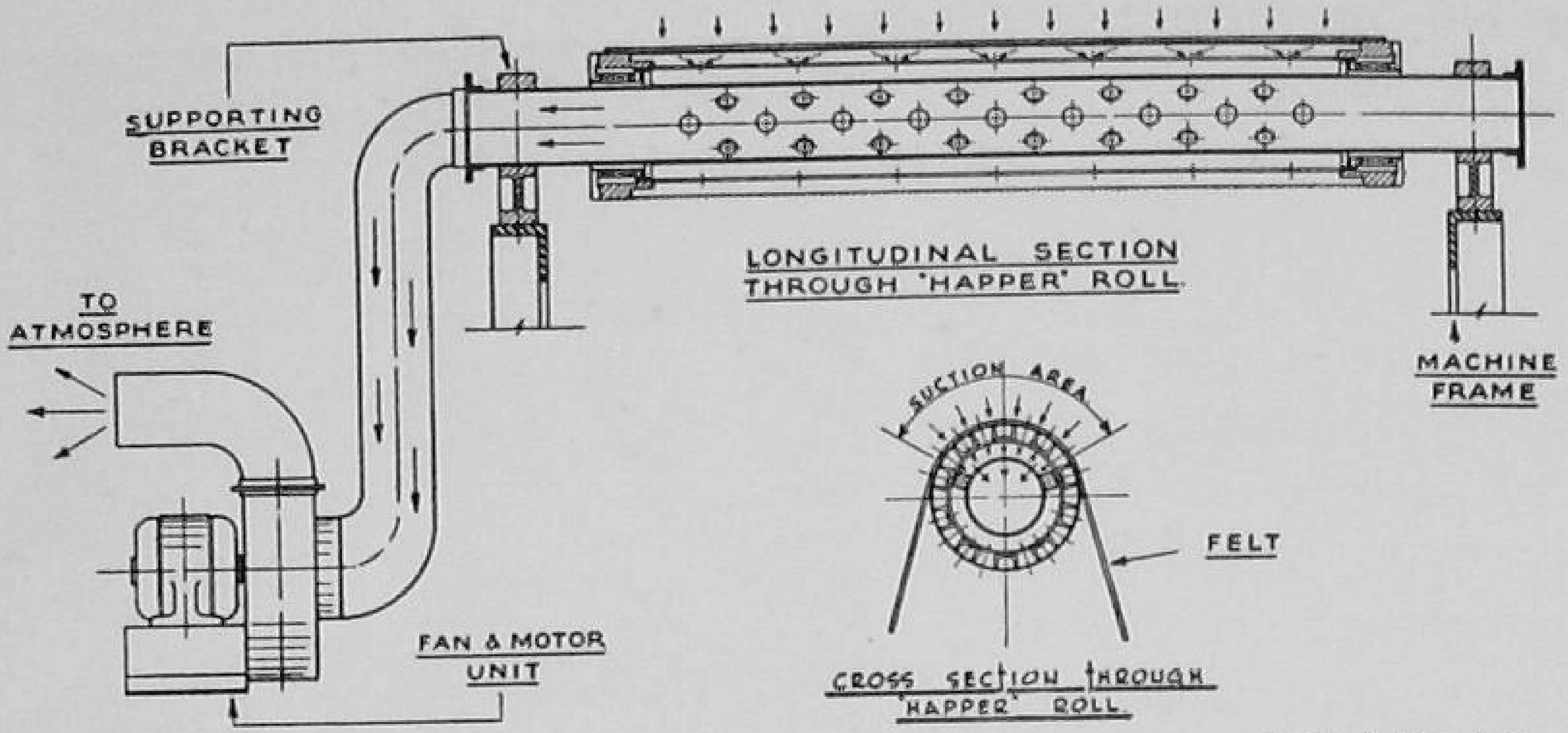
Fig. 150.—The Happer Felt Dryer

are drawn right through the felt into the inside of the roller and conveyed by fan and delivery duct out of the machine house. In addition, the rollers are wound with a bronze wire in such a way that wandering of the felt is greatly reduced.

It will thus be seen that this method not only conditions the felt, but has the added advantage of removing some of the moisture-laden air from the room, or at least it does not allow this moisture-laden air to be blown into the room.

By placing a number of these rollers at suitable positions among the drying cylinders the felts are maintained at a much higher average standard of dryness than can possibly be attained by some heated cylinders, and there is not so much danger of the browning or burning of the felts. The felts are evenly dried across the full width of the web, and the moisture is drawn right

through, thereby keeping the felt in much better condition, and more open and porous.



[*Hall & Kay Ltd.*

FIG. 151.—DIAGRAM OF THE HAPPER DRYER, SHOWING THE INTERNAL CONSTRUCTION AND THE PATH TAKEN BY THE AIR THROUGH THE FAN TO ATMOSPHERE

From our own experience we can say definitely that these 'Happer' rollers are by far the best method yet introduced for the satisfactory conditioning of dry felts, and for ensuring evenness of drying across the full width of the web.

The Heimbach system works on the opposite principle and blows dry air through the felt into the machine house. This air becomes saturated by taking up moisture from the felt, and has to be extracted from the room by means of fans.

Smoothing Rolls.—These are two steel rolls, steam-heated, and are inserted before the last section of drying cylinders. Their purpose is to smooth or flatten the web of paper while it is still in a slightly damp condition. They reduce bulk a good deal, but, if rightly used, are very effective in eliminating felt marks, and, by closing up the under side of the sheet, produce a very equal-sided paper. They should be run fairly hot, but not excessively so.

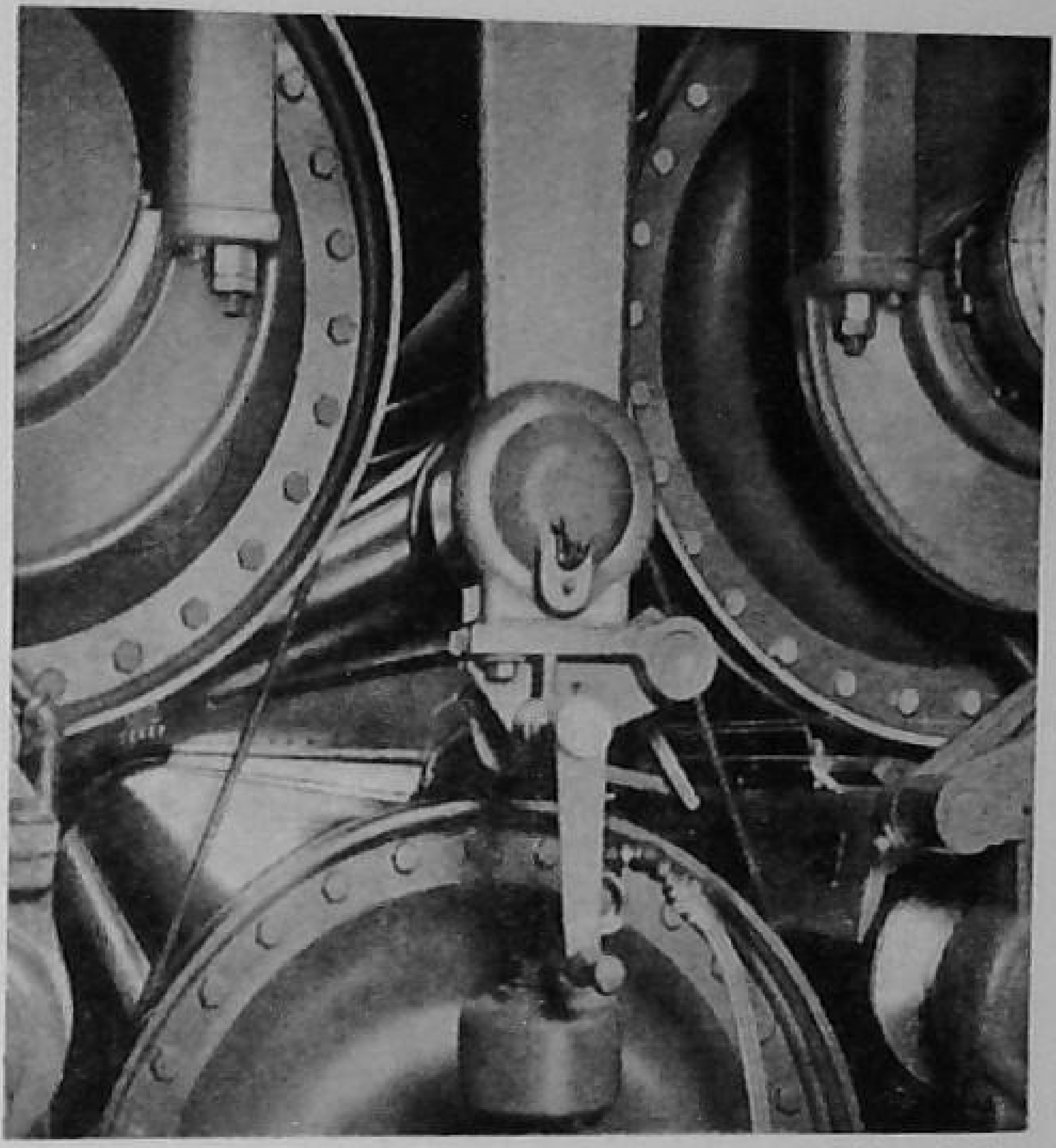
Good doctor blades are necessary for both rolls, as any particle of stuff or dirt may stick very firmly to their surfaces owing to the heat used.

The flexible doctor (Figs. 152, 153 and 154) has revolutionized 'doctoring' of all rolls on the paper-machine, and it is rapidly displacing the older forms of rigid iron doctors in most positions. It consists of a row of springs fixed to a rigid holder, and these springs are slotted to take a flexible thin steel blade. It will be easily understood that this flexible doctor blade readily accommodates itself to any irregularities on the roll, and to variations in the position of the roll—that is, when paper is being led through at one end, and so tilting the roll out of parallel with the doctor support.

In order that the blade may take up these distorted positions, it is obvious that it must be capable of moving sideways, as the distance between the ends will be less in these positions. The blade, being only lightly held, can slide sideways to make up for these distortions.

Being thin and of light construction, the doctor rapidly responds to differences of temperature, such as the heat of calender rolls, M.G. cylinders and intermediate rolls. It keeps the surface clean and polished and in good condition.

The blades never need to be filed and fitted and they last fairly well, even on fast news machines.



[*Vickerys Ltd.*

FIG. 152. — APPLICATION OF VICKERY DOCTORS TO DRYING CYLINDERS

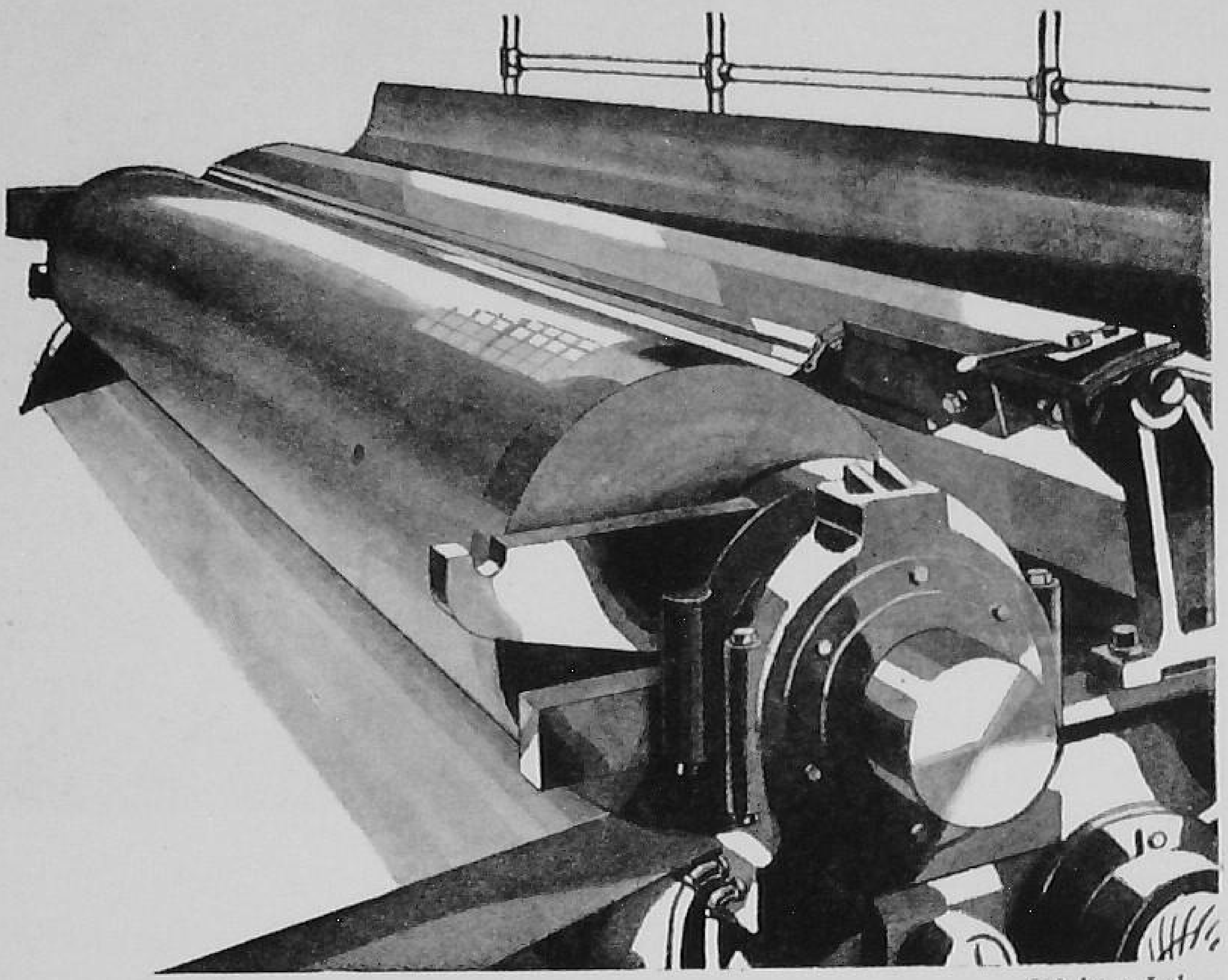
The blade itself, when worn out, is very easily replaced, only a few minutes being required, in place of the hours often necessary with the older types of doctor, which had to be filed until they fitted approximately.

A new type of blade is being used with great success for keeping rolls clean. This is made of a bakelised cotton substance which takes on a very keen edge, and seems to be self-sharpening. It can be used on breast rolls, wire rolls and press rolls, and fits more snugly to the roll than an iron doctor. It has many advantages over wood and iron, and is less likely to groove the surface with which it comes in contact.

Calender Rolls (Figs. 154 and 155).—Most machines making E.S. papers have three sets of five rolls each. A very good machine finish may be got with these, but some machines are fitted with as many as five sets, of which the first two sets may be of three rolls each. All rolls are cambered to take an increasing weight towards the reel end, and are fitted for steam heating, and have doctors and guards before each ingoing nip. The bottom roll of each set is greatest in diameter and is driven. The other rolls are driven by the friction between their surfaces and the paper.

After passing through the calender rolls the paper will have received its surface finish, and as a result of the heat and friction of the rolls, it is always charged with static electricity. Sometimes this charge is very high, especially

so when the rolls are very hot and the paper has been allowed to get a little too dry. Then trouble is experienced with the laying of the sheets when the



[*Vickerys Ltd.*

Fig. 153.—Vickery Flexible Doctor applied to a Press Roll

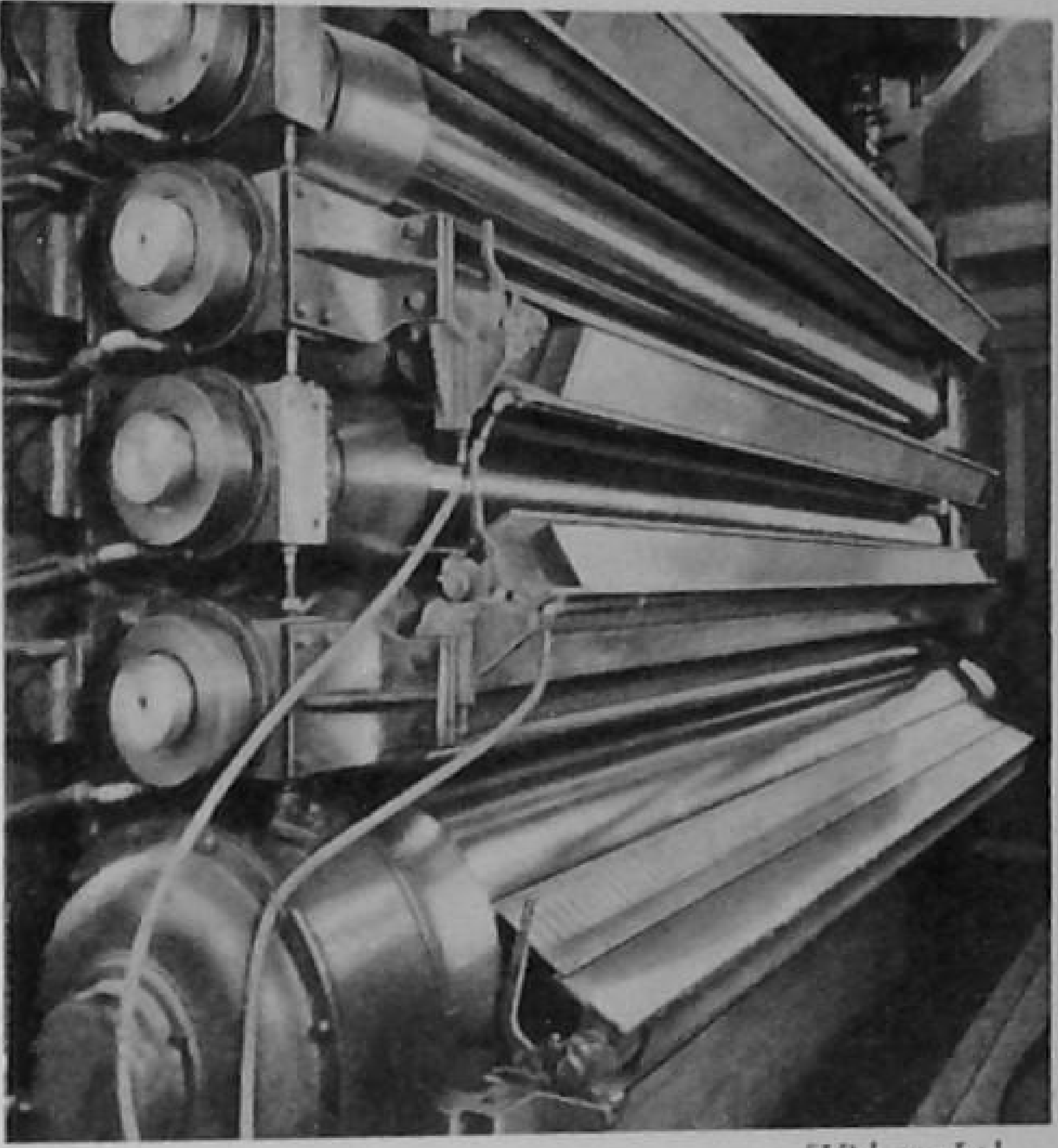
paper is being cut. They are attracted to parts of the cutter and also to each other, which interferes with the 'picking' or overhauling later on. To cause this electricity to be discharged the paper is led from the calenders over a water-cooled cylinder or cylinders. Where these are not fitted, copper wires are stretched across the machine, close to the surface of the web, and earthed to a water pipe or to the frame. Conditioned paper is, of course, freed from all static.

Damping.—It is frequently desirable to damp the paper on the paper-machine before it is reeled up. This helps to cool it and to put back into the paper part of the normal humidity which the paper would contain. It also helps considerably if the paper has to be immediately supercalendered.

Damping is often done in addition to passing the paper over a cooled drum reel. There are a number of spray dampers available for this purpose, notably the 'Orion' which is illustrated, and also the Watford 'Aquamist' illustrated in another chapter.

The principle of damping is to provide a very finely divided spray of

water mist, either on one side of the paper or on both sides, every care being taken to see that no large drops of water find their way on to the sheet. This fine mist is immediately taken up by the hot paper.

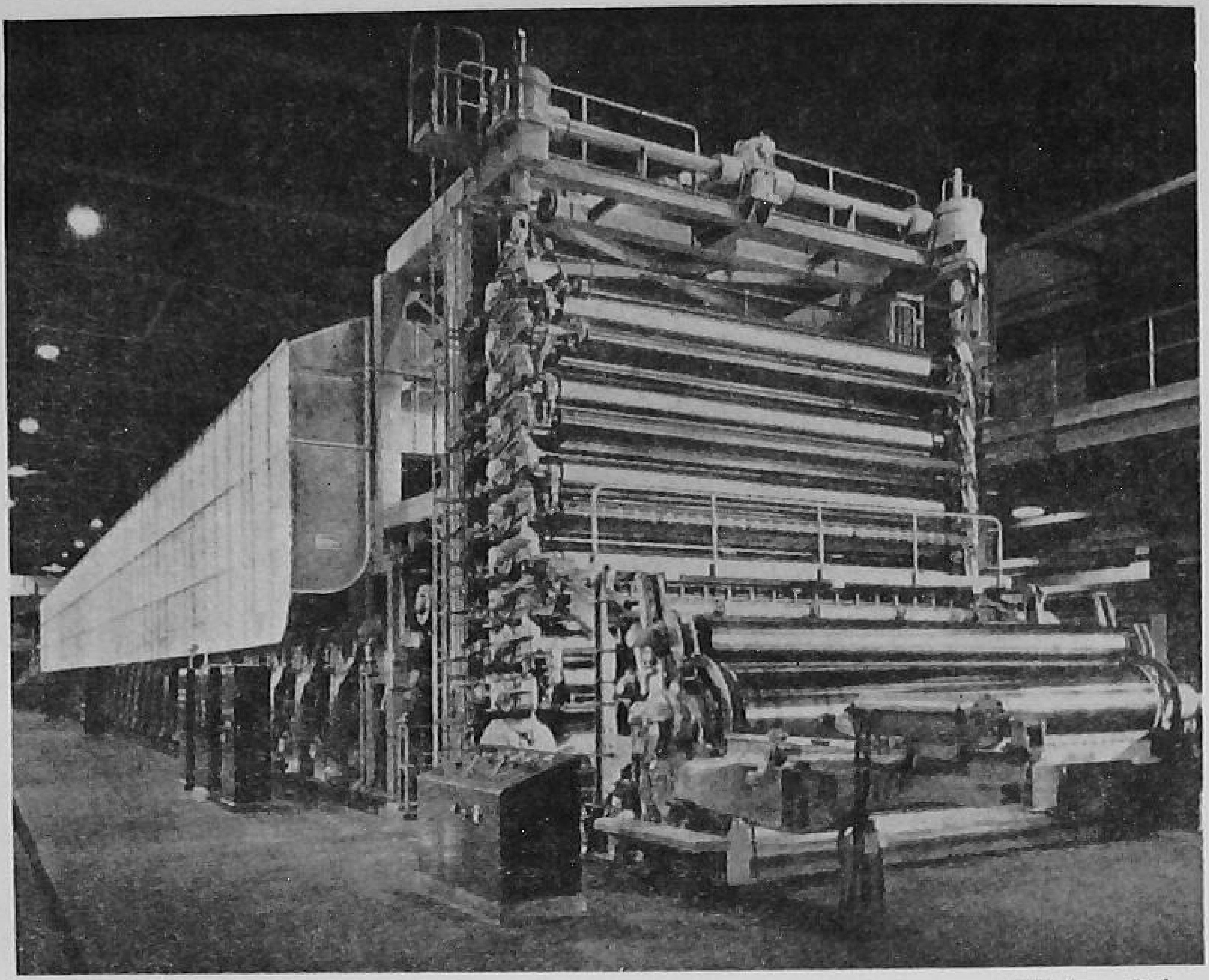


[*Vickerys Ltd.*

FIG. 154.—APPLICATION OF VICKERY DOCTORS TO CALENDER ROLLS

Paper Machine Reel-up.—A number of different methods are used for reeling up paper at the end of the paper-machine. Originally big sparred drums were used, revolving at the same speed as the dryers, and the paper was wound into very large drums on these, and afterwards was often cut off with a knife into big slabs, and laid on a table. Nowadays there are two or three different methods in general use, one of them being the friction type reel-up, in which the paper is wound on a wooden or metal shell which is driven by a slipping belt, and of which the drive is also controlled by brakes. As the reel of paper revolves at different speeds, according to the diameter, variation in the speed of the reel has to be made, in order that the tightness of the paper is more or less the same for the whole of its length on the shell, or reel box. This method of reeling up is in very general use, but only at the slower speeds, and the tightness of the paper on the shell varies according to the way in which the dryerman or reelboy operates the brake which controls the speed at which the reel box is driven.

When the newsprint machines became very much higher in speed than the normal general purpose Fourdrinier machine some new reel-up technique was needed, and the drum reel was brought into use. In this method of reeling up a large drum is driven from the machine drive, and the metal shell on which the paper is to be wound revolves on this drum by friction, being held on to the drum by gravity and supported by arms which are movable and can lift up as the roll of paper becomes larger. The paper is passed from the end of the machine on to the drum and round the shell, on which it continues to be wound by its own weight and by the friction drive of the drum. As the reel grows larger and larger the arms, which are loose, allow the shell to be lifted away until the reel attains its maximum diameter. These drum reel-ups have been brought to a very high state of perfection nowadays, and many of



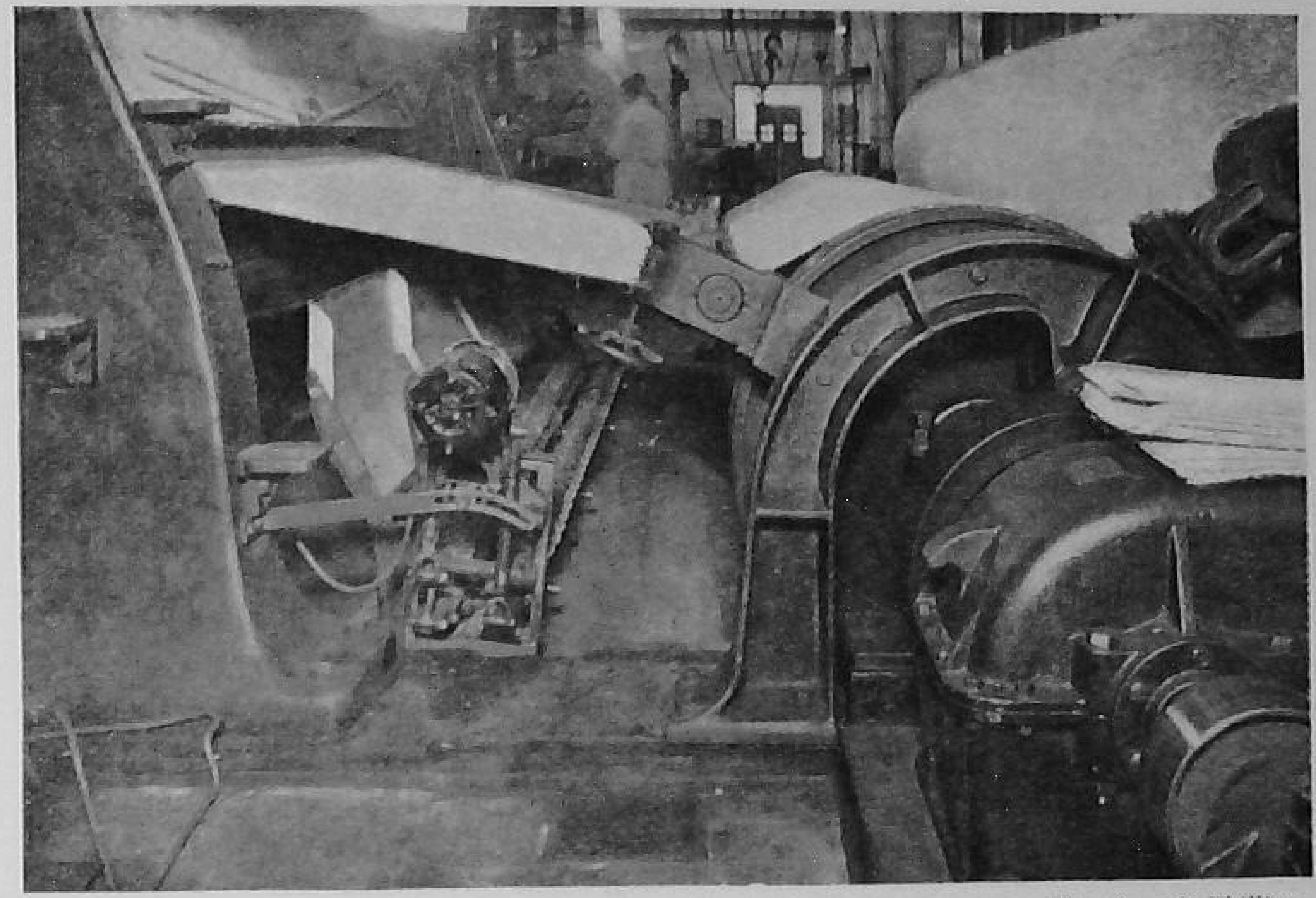
[Vickerys Ltd.

Fig. 155.—Dryers with Hood, large Machine Calender Stack, with Vickery Doctors, and Drum Reel-up of large Fourdrinier Machine

[Sternberg & Phillips

Fig. 156.—Orion Spray Dampers arranged between Calenders and Reel-up on Fourdrinier Machine

them have an automatic change-over, so that when the roll of paper reaches the desired size, the paper breaks and is taken on to a new shell without any



[Sternberg & Phillips

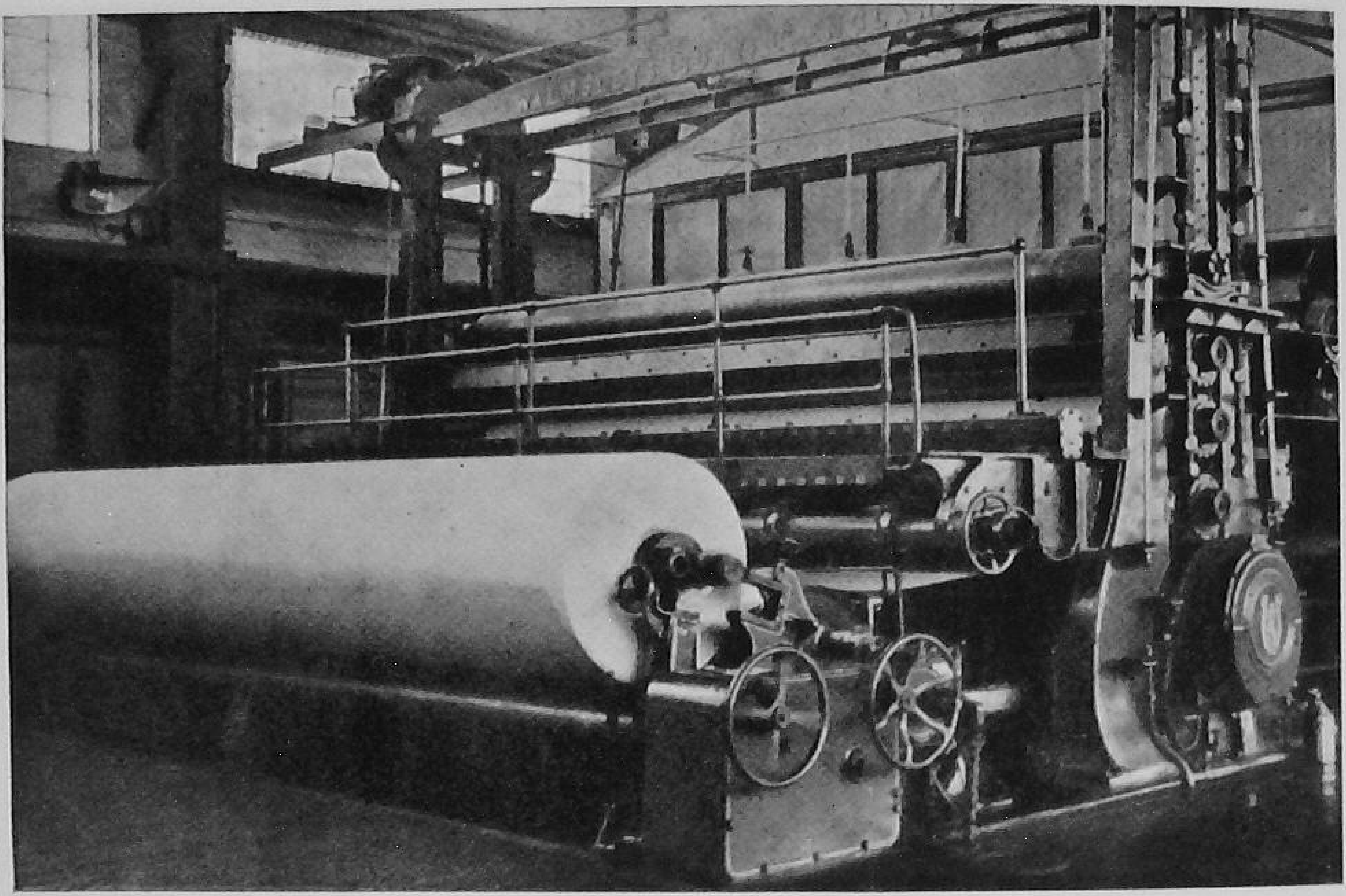
Fig. 157.—Arrangement of Orion Spray Dampers for underside of paper before Reel-up

broke being made, the full reel of paper being immediately taken away by means of lifting tackle on a runway. By using this method of reeling up a very hard roll of paper is made, which can be run off on rewinders or cutters at very high speeds. It is important, however, in order to get a good reel of paper, that the flow on to the wire should be very even, and the weight and substance variation across the sheet should be reduced to the minimum, otherwise piping, and even creasing, may occur.

The saving of broke by this drum reel-up method is very considerable when compared with the friction type reel-up, and it also takes away to a great extent the human element, and makes it very much safer to start up a reel of paper than with the old method when the men had to put the sheet round the roll by hand, judging, so far as they could, the correct tension and the correct amount of brake to put on the reel. This is not so important with very thick and strong papers, but is an extremely difficult operation when very thin papers are concerned.

Since the speeds of paper-machines have been increased very considerably in recent years, the friction type reel-up became unsuitable for high speeds, and has been replaced by the drum reel, on which the reel of paper is wound by contact with the driven drum. The drum is usually a small cylinder,

water cooled, and the gearing to operate the arms carrying the steel sheet is generally arranged for automatic change-over. When the roll of paper is



[*Walmsleys (Bury) Ltd.*

FIG. 158.—PAPER REEL-UP AT THE INSTANT OF STARTING THE CHANGE-OVER MOVEMENT

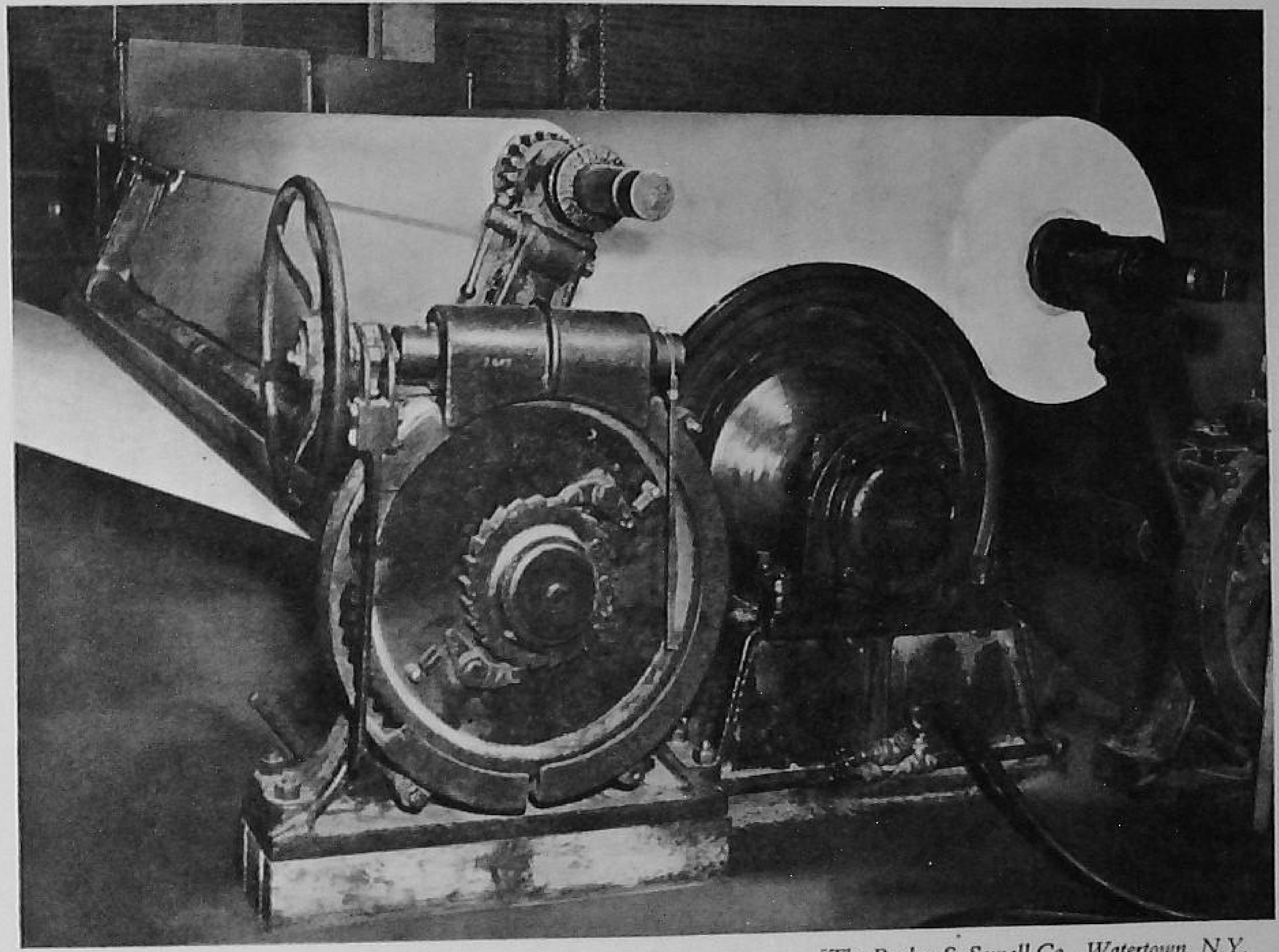
large enough, an empty steel shell passes into place on the drum. The paper is broken and immediately winds itself round the new shell; the full roll is lifted clear by means of an electric crane, and the change-over is accomplished without the loss of any paper. The 'Pope' reel is a good example of this type, and is illustrated in Fig. 158 in the act of changing over from a full roll to a new shell.

It will generally be found advisable to cool paper before reeling it up on a drum reel, in order to avoid piping and creasing.

There are a number of excellent drum reel-ups available, some of which can be operated to change the reel almost automatically. Among these are the 'Pope' reel, the 'Vickery' change-over reel and one made by Bagley & Sewall; these are illustrated in Figs. 158 and 159.

There are also other methods used for reeling up, and these are electrically controlled, so that a reel of any desired hardness may be wound. On very thin tissues it is often desirable to wind the rolls very slack, as for crêping. The variable speed electric reel-up is very satisfactory for achieving

this. Siemens and Metropolitan-Vickers both make this type of reel-up (Fig. 160).



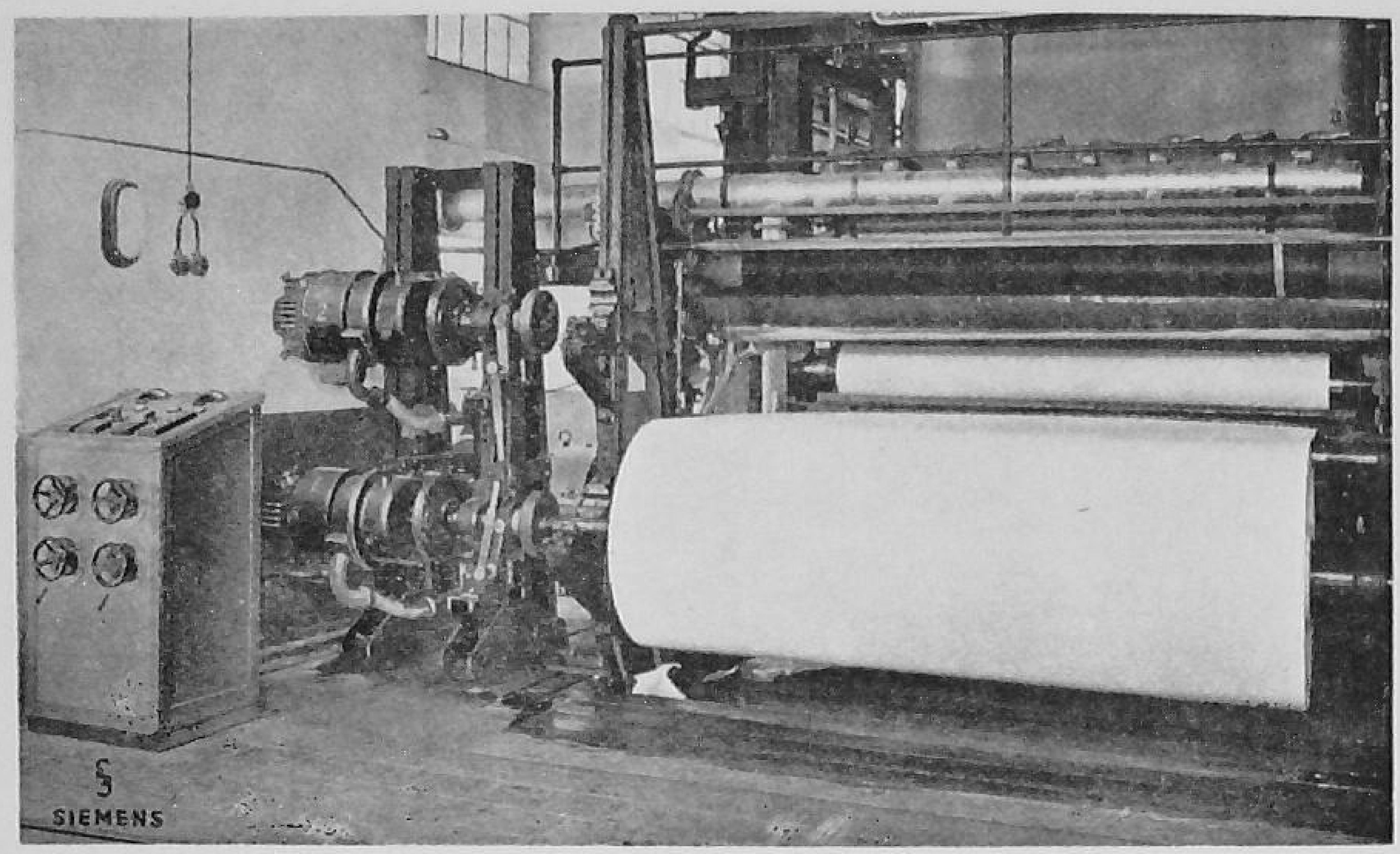
[The Bagley & Sewall Co., Watertown, N.Y.

FIG. 159.—DRUM REEL-UP, SHOWING A REEL BEING WOUND ON THE DRUM, AND ANOTHER REEL READY TO TAKE ITS PLACE. THE CHANGE-OVER MECHANISM IS ALSO SHOWN IN THE FOREGROUND

The Machine Drive.—The 'drive' is the term used to express the means by which the various sections of the machine are connected to the source of power, and includes the latter. Formerly one steam engine was used to drive the various pumps, etc., of the wet end and also the machine itself. In still earlier times it was not unusual to find a water wheel doing the work. The means of power transmission was by belts and shafting geared to the engine with spur wheels; as the wet end machinery cannot be varied very much in speed, the range of speed for the machine was very limited.

To overcome this difficulty, intricate arrangements of 'speed wheels' were used when very heavy or light substances were being made. This entailed shutting down and lifting on and off heavy gear wheels, or putting intermediate wheels and shafts into action. Later on two steam engines were used, of which one drove the wet end at a constant speed and the other the

machine itself from the wire onwards. This was a great improvement, but the steam engines were of too heavy a type, with a limited range of speed,



[*Siemens-Schuckert (Great Britain) Ltd.*

Fig. 160.—Variable Speed Electric Reel-up, enabling Hard or Soft Rolls to be made

and 'speed wheels' were still necessary. Their heavy flywheels, parts and long stroke prohibited a high speed, so there was only a limited range of speed at which they could be used with any efficiency.

The reciprocating action of these heavy engines caused the belts to swing, and the sections of the machine were very jerky and unsteady, and this was the source of endless broke.

Many had no variable governor drive, and the speed was altered by hanging more or less weight on the governor lever. As the necessity for higher speeds arose, and to dispense with the inconvenience and loss of shutting down to change speed wheels, the smaller type of high-speed light engines was developed, and proved a great advance in steadiness and efficiency.

In the old type of belt drive the usual arrangement comprised a series of gear wheels of various sizes, which had to be changed to suit the speed required. The first press rolls were driven direct through a clutch on the main shaft. On this shaft were three pulleys, from which one belt drove the wire shaft, one the shaft for the main stack of drying cylinders and the third the shaft for the second press. On the cylinder shaft were the pulleys of the smoothing rolls, the second stack of drying cylinders and the calender rolls.

From one or other of the calender roll shafts, belts extended to the cooling rolls, winder, etc.

The sections of the machine were put in gear by means of toothed clutches, which started them up with a sudden jerk, imposing a great strain on the belts, and specially on the teeth of the cylinder gearing. In fact, the engine had to be slowed down to put the cylinders into motion, and unless this was done the wheels were sure to be stripped of teeth.

The tension of the 'draws' was regulated by sticking on the pulleys, to increase their diameter, pieces of 'packing', strips of old coucher covers, old dry felts, etc., by means of resin boiled with oil and pitch. This had to be done when the machine was running, and was a troublesome, difficult and dangerous operation. The tendency of the pull of the belts was to drag the 'packing' into lumps, and in hot weather the resin refused to remain sticky enough, so that pieces fell off and had to be continually replaced. When a piece of packing could not be got off a pulley, a piece had to be stuck on the other to get the draw correct, and the belts frequently stretched and broke under the strain. The provisions of the 1937 Factory Act preclude the use of this type of drive.

The introduction of the high-speed engine and variable speed electric motors made it possible to arrange a drive which has none of these faults. Instead of heavy belts in series, the engine drives a shaft, usually overhead, from pulleys on which each section is separately driven through bevel wheels, the smaller of which is of hide, giving a smooth and noiseless motion. Light belting (4 to 6 inches) is used, and cone pulleys supersede the packing method.

In another type—'White's drive'—the power is transmitted by a system of ropes instead of an overhead shaft, and cone pulleys with light belts are used to vary the speeds of the sections. No clutches are used, the driven cone pulley being raised by a lever so that the belt is put out of action, and has no wear and tear unless the section is being run. When starting up, the pulley is lowered into the loop of the belt and the section starts gradually as the belt is tightened up. This has shown itself to be a very efficient, smooth and steady drive.

The Marshall Drive.—The Marshall drive transmits power to the various driving sections of the machine from a line shaft running parallel to the length of the machine. Each unit allows a certain amount of speed adjustment, and turns the drive through a right angle to couple to a driving shaft which lies in a cross-machine direction.

In every stage of its development the unit has consisted of a shaft carried by bearings and stands from the machine house floor, and driven from the

line shaft by clutch-operated cone pulleys, the latter being provided with belt-regulating gear to give speed adjustment. The shaft of each unit has fitted at one end a bevel pinion which gears with a bevel wheel on the section driving shaft.

The advances made in the design of the Marshall drive since its first inception consist mainly of improvements to the gear wheels, and the replacement of ordinary bearings by anti-friction bearings of the roller or ball type.

The first arrangement of gear wheels would almost certainly have an iron pinion with cast teeth, working in conjunction with a mortise wheel having teeth of hornbeam or birchwood fitted into a cast-iron rim. Later, both wheel and pinion would have cast teeth, and then in turn these would be replaced by gears with machine-moulded cast-iron teeth, and eventually by machine-cut teeth. Up to this period the gear wheels had worked without any serious attempt being made to enclose them, and lubrication consisted of an application by hand of heavy oil or grease at frequent intervals. With the advent of bevel gears made from high-tensile steel and having spiral teeth, the Marshall drive entered the field of precision engineering. Gears that were now only about half the diameter of the originals, but transmitting the same power, required protection both from dust and from the effects of faulty lubrication. It thus became necessary to enclose the gears in cases that were both dust- and oil-tight.

These modern units with gears running in oil, on shafts equipped throughout with roller bearings, occupy a minimum amount of space and are practically noiseless in operation.

Most machinery manufacturers make a range of units of various power capacities, each with variations in gear ratio. Their design allows ample adjustment to be made to take up wear in the taper roller bearings, and also has ball bearings fitted for the cone pulley to revolve upon when the unit is not transmitting power.

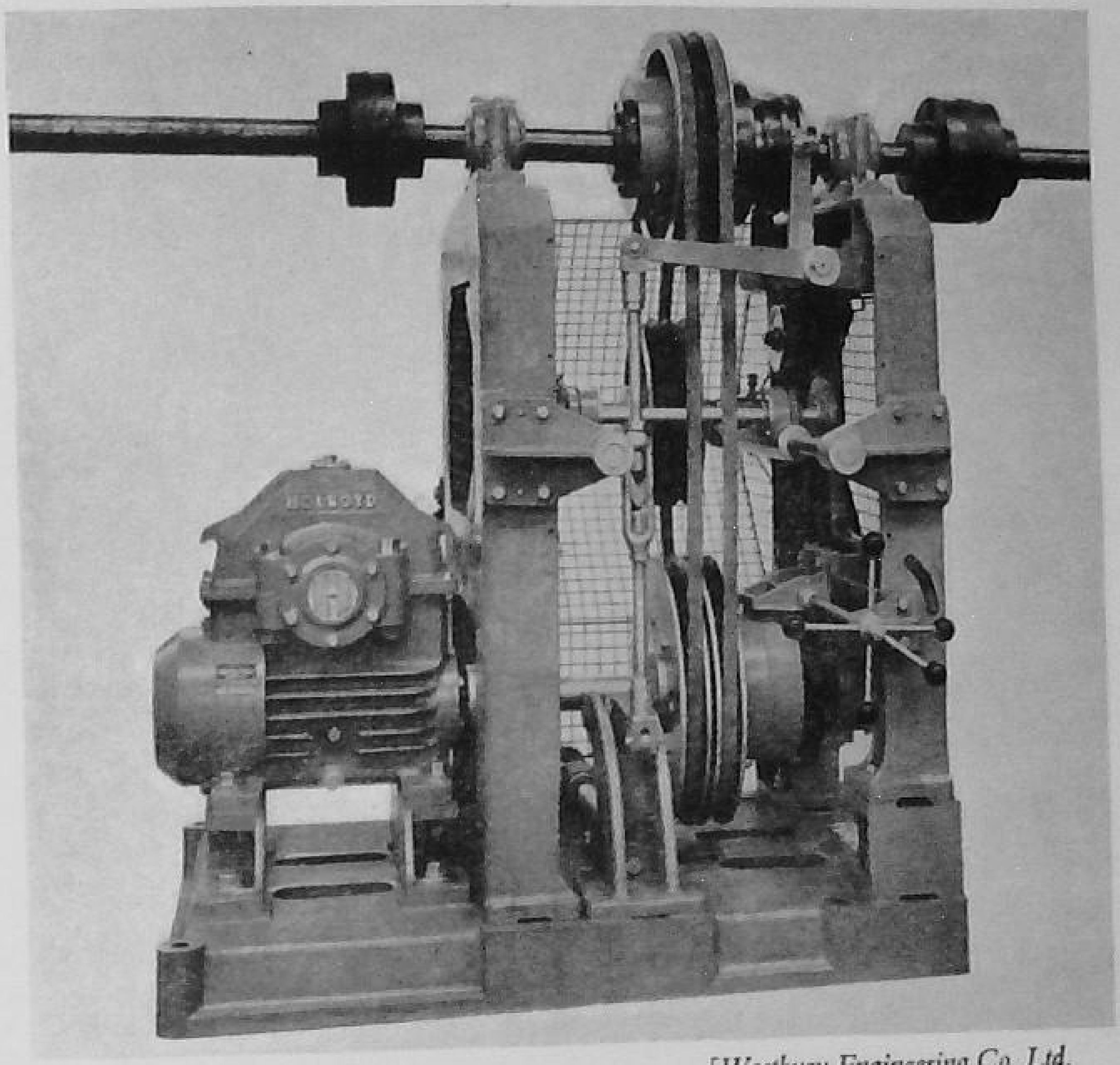
The power unit for the Marshall drive consists of a variable speed motor, such as a British Thomson Houston commutator motor, or the Laurence Scott A.C. variable speed induction regulator type motor with fixed brushes.

The *Heys Vari-Vee Drive* was developed to meet several requirements and characteristics hitherto not found in a mechanical drive for paper- and board-making machines.

Ordinary flat belts have certain disadvantages and it was with this in mind, that careful consideration was given to the endless 'Vee' rope, manufactured from fabric and rubber, as a driving medium.

Several attempts to make a reliable expanding and contracting 'Vee'

rope pulley have been made, but it is only in latter years that a really successful device of this kind has been tried and proved.



[*Westbury Engineering Co. Ltd.*

FIG. 161.—UNIT OF HEYS VARI-VEE DRIVE, SHOWING GEAR, 'V' PULLEYS, JOCKEY PULLEY, AND ADJUSTING LEVER FOR VARYING DEPTH OF GROOVE IN PULLEY

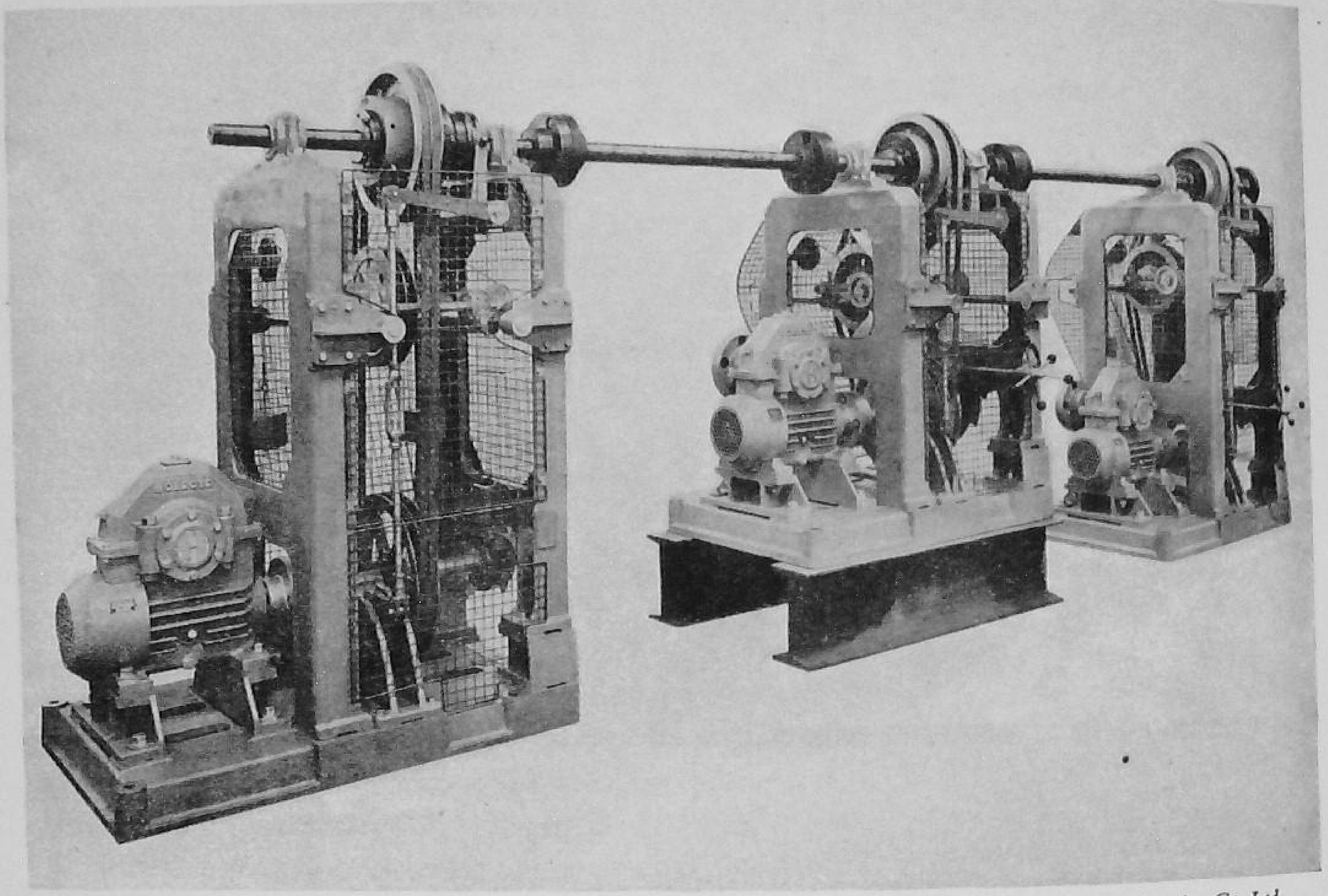
It will be appreciated that a well-designed pulley of this kind forms the heart of the drive now being considered, and merits the attention when one is faced with the problem of installing such equipment.

The following is a description of this apparatus, together with its undoubted advantages.

The complete drive comprises a number of gear units, each coupled to a section of the paper- or board-making machine, and the whole arranged to operate from a lineshaft, the latter being coupled to a prime mover capable of variable speed (Figs. 161 and 162).

Each section has a cast-iron baseplate, at one end being located either a worm gear or some form of spiral bevel gear. On the high speed side of this gear box is to be found an extended shaft on which is keyed a multi-grooved variable 'Vee' rope pulley, capable of an individual stepless speed range of approximately 12 per cent. This pulley is operated by means of a small worm gear, and can be actuated either by a handwheel at the rear of the machine, or by means of some form of electrical gear with push button at the front of

the machine. Two vertical stands are bolted to the above-mentioned base-plate and serve the double purpose of carrying the lineshaft and an automatic



[*Westbury Engineering Co. Ltd.*

FIG. 162.—THREE UNITS OF HEYS VARI-VEE DRIVE FOR PAPER MACHINE, WITH MASTER LINE SHAFT, GEAR BOXES, CLUTCH OPERATING GEAR, AND EXPANDING PULLEYS

rope tensioning apparatus. This is a specially designed grooved jockey pulley mounted on rack bars with sliding brackets, pinions, wire ropes and weights. The jockey pulley readily adjusts the working tension to the 'Vee' ropes when a speed alteration is made. It is very important that 'Vee' ropes work at the correct tension, this being necessary to ensure absence of slip and maximum power distribution. Each gear unit is fitted with a multi-plate friction clutch, or if preferred, some other form, such as the magnetic or compressed air operated type. Whichever is employed, the clutch is actuated from the front of the machine. Special care has been taken to enable new ropes to be fitted when the need arises. This is accomplished by removing a disc from a coupling on the lineshaft near the gear unit, and also a removable piece on one of the vertical gear stands.

The Heys Drive can be arranged with the lineshaft overhead, in a basement, or on the floor of the machine room.

The whole equipment occupies the minimum of floor space, is compact and fitted throughout with anti-friction bearings.

[Harland Engineering Co. Ltd.

FIG. 163.—HARLAND DRIVE ON 200-INCH BOARD MACHINE

According to the power requirements of the various sections of the paper- or board-making machine, the number of 'Vee' ropes used varies and whenever possible the manufacturers aim at standardization, and employ pulleys of 3, 4, 5 and 7 ropes.

This form of drive not only runs smoothly, but can be designed to transmit great power at either slow or fast web speeds. The speed adjustment on each section is infinitely variable, steady and simple in operation. High momentary starting torques are allowed, as unusual circumstances often occur on a paper-machine when starting up from rest. These and other points have been thoroughly investigated by the makers in arriving at the ultimate details and design.

Multi-Motor Drive.—The Harland drive (Fig. 163) is of the sectionalized type with a motor on each section, the motors being coupled through double helical gears to the paper-machine driving-in shafts. For the purpose of maintaining relative desired speeds on the motors, a master reference is provided. In the original system a light shaft was run along the full length of the machine, this shaft being driven from the dryer section or by a separate

master motor. In the up-to-date version an 'electrical master shaft' is employed, giving greater flexibility of layout and control.

Each section is provided with a differential regulator, one shaft of the differential gears being coupled to a small synchronous motor running in synchronism with the master alternator. The second shaft of the differential gears is driven by means of a belt and cone pulleys from the motor to be controlled, while the third member of the differential actuates the special shunt regulator in the motor field.

The speed of the master alternator determines the speed of the paper-machine. It is direct coupled to a small master motor.

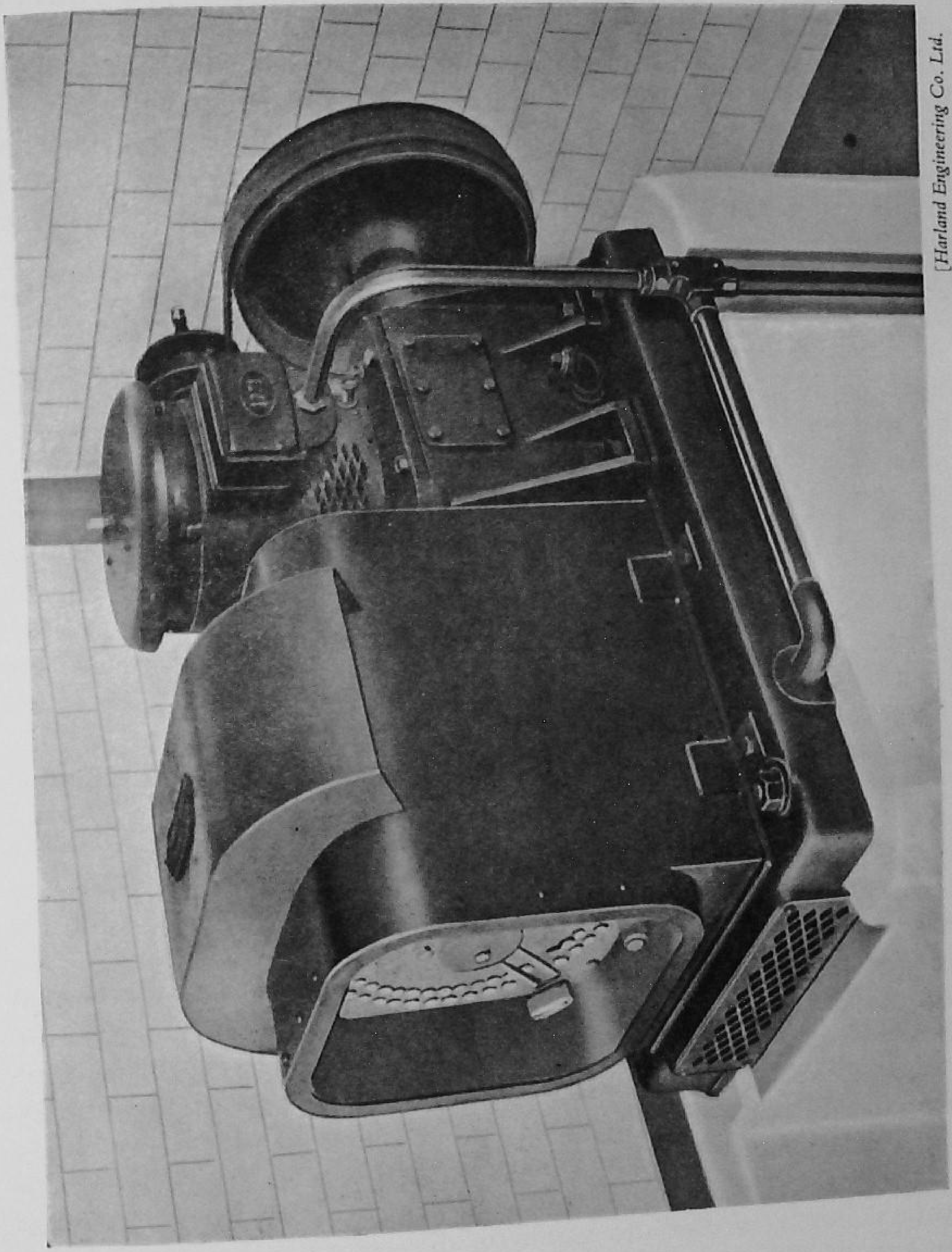
As is well known, the speed of the third member of any differential gear is the resultant of the speeds of the other two shafts. When the first and second shafts are running at the same speed in opposite rotation, the third member, which is connected to the regulator, will remain stationary. Immediately there is any difference in the speeds of the first and second shafts, the regulator will move in the required direction to correct the motor speed. If the load changes—say, increases—the motor will tend to run slower, and as soon as this happens the first and second shafts will not be in equilibrium, and the third member will move the regulator and weaken the field until the two shafts are running at the same speed again. If load is thrown off, the reverse action takes place.

The system is absolutely positive, the three members of the differential gear being mechanically locked together, and the smallest change in speed between the first and second shafts is at once shown by movement of the regulator.

Correction of an error in section motor speed is made very quickly, the response of individual regulators being designed to take into account the differing characteristics of inertia and frictional damping to give maximum drive sensitivity without hunting, the accuracy of control being such as to avoid strain on the web of the paper.

A view of the differential regulator unit and the small synchronous motor is shown in Fig. 164. The differential gears are housed inside the regulator case, while the cone pulley shaft projects at the back of the case.

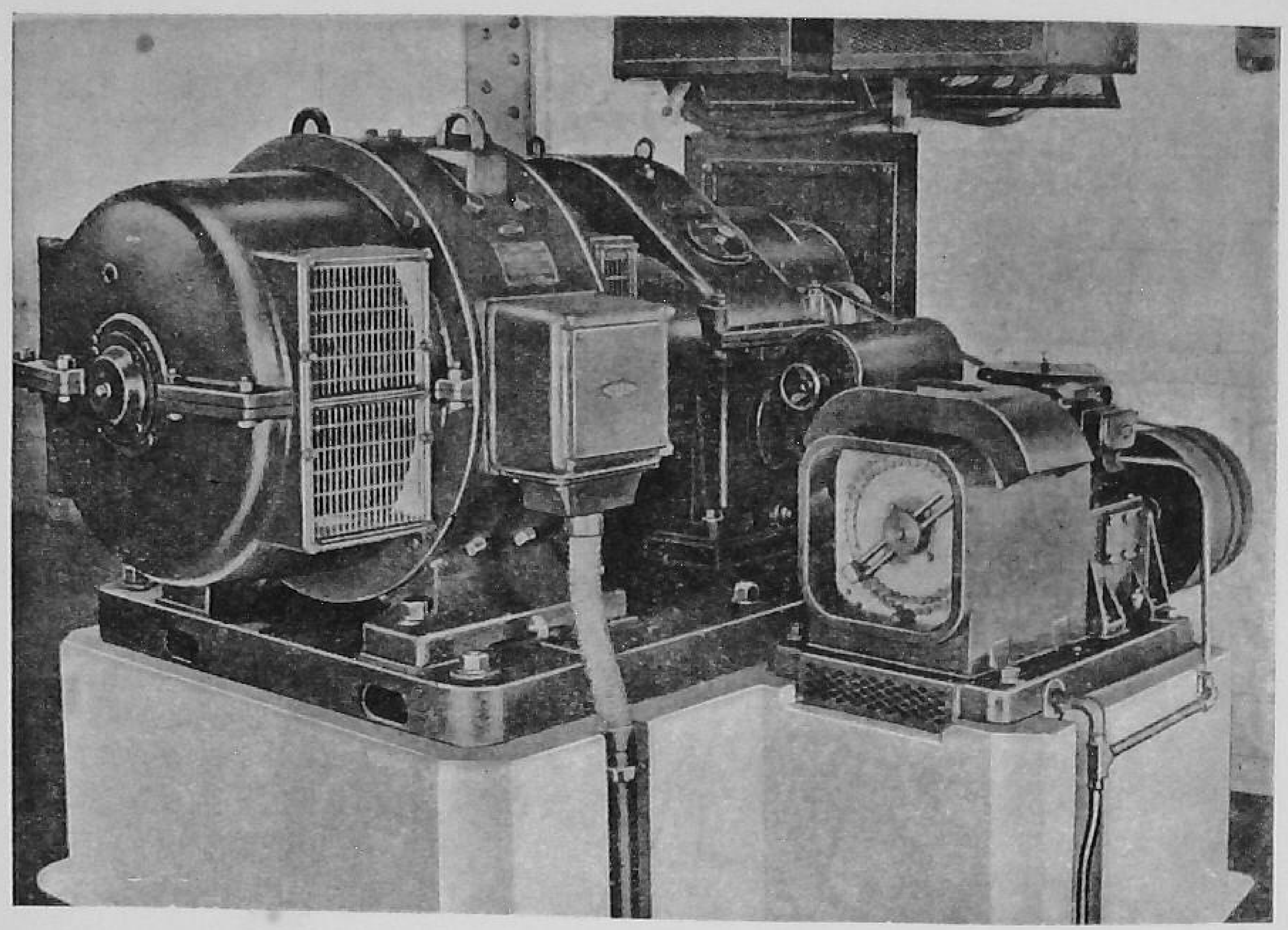
In Fig. 165 is shown a typical section motor with interlock equipment and cone pulley transmission to enable the draw of the section to be varied. Suppose the belt is in position as shown in the illustration and it is required to alter the draw by decreasing the speed of the motor, the belt must be moved by means of the belt-shifter towards the large diameter of cone on the motor shaft; this increases the speed of the second shaft of the differential gear and causes the regulator to move and reduce the speed of the motor



[Harland Engineering Co. Ltd.

FIG. 164.—THE HARLAND INTERSECTION SPEED REGULATOR UNIT

until the second shaft coincides in speed with the first shaft. The regulator arm has now assumed a new position on the faceplate, giving the required field strength for the new speed.



[Harland Engineering Co. Ltd.

FIG. 165.—HARLAND DRIVING UNIT

The draw is increased or decreased without breaking the paper or interfering with the running of the machine.

The drive takes up very little space, and may conveniently be housed either alongside the paper-machine or outside the machine room in an annexe, with the driving-in shafts passing through the wall or partition, as shown in Fig. 88. It is very compact and accessible, and does away with all troubles from belts, ropes and clutches.

The drive is very efficient and provides great flexibility of layout both from the point of view of mechanical arrangement and control. In particular, the drive to each section of the paper-machine can be designed to suit the inertia and frictional loading characteristics to ensure equal accelerative response on all sections to any common change in speed, thus relieving the paper of tendency to tighten or slacken between sections under such conditions. The speed of the whole paper-machine can be maintained so constant as to limit the variation to a fraction of 1 per cent, a factor of

considerable importance for high-speed paper-machines. All control can readily be arranged at the front of the machine in the most desirable positions for machine speed as a whole, section motor inching, crawling, starting and stopping and draw adjustment with local indication of speed, power requirements and draw settings. Individual sections of the machine can be shut down, inched or crawled without affecting the correct interlocked running of the remainder. Heavy sections can be electrically braked for quick stopping, thus minimizing delays and tending for safety in the event of accident.

The ease of control, speed constancy and reliability of this form of drive combine to give maximum output of highest grade product, and it is not surprising to find its application being extended to all classes of paper-making machine, both large and small.

The British Thomson Houston Company also make a sectional electric drive which is in use on paper-machines, and a recent improvement is the separate driving of each individual cylinder which has been developed by Siemens, who were licensees for the Harland system. For certain papers this system possesses definite advantages.

CHAPTER XVIII

PAPER-MAKING ON THE MACHINE—WATER-MARKING

Notes on Machine—General.—As paper-making on the machine varies so very much with the qualities, substances, etc., of paper, it would be futile to attempt to lay down hard-and-fast rules as to how the various parts of the machine should be used. The machineman has to exercise his judgment, and must have at his command numberless 'dodges', if we may be allowed to call them so, for getting the results he wants.

As far as the strainers there is little that may be called 'paper-making'. It is when we get the stuff to the wire that the art and skill of paper-making commence. The slices are the first consideration, and these have more to do with the look and strength of the sheet than may be supposed. On some machines there is a lifting gear to raise or lower the breast roll end of the wire frame. A low level will cause a deep 'dam' to form behind the slices, and a deep pond will remain after them. Under the influence of the shake this might be expected to close up the texture of the sheet, but it is not always so. The rising slope of the wire will result in the stuff and water rolling over and turning on itself, and a cloudy, though well water-marked paper will be made. This is what is generally wanted for laid ledger papers of a certain class.

By raising the breast end a little the stuff will flow out from the slices more freely, and though not being so long under the influence of the shake, will produce a closer-looking sheet.

The same result can be obtained by increasing the speed of the machine, and taking the stuff away from the slices before it can get time to roll back. Thus if the breast end is fixed at one level, the speed of the machine may be used to do the same work as a lifting gear. Again, if we have a deep dam behind the slices—that is, the slices close down on the wire—the stuff will shoot out and forward, and go well up the wire, and get very little good from the shake. Also, the fibres will be turned round and set on edge by being forced through a very fine opening. This makes a raw and badly water-marked sheet.

By raising the slices the fibres will flow gently on to the wire, and the shake will get hold of them at once where the longest throw occurs. Then the fibres will be well felted and closed up, and the sheet will be found to be stronger and closer in texture and have a clearer water-mark.

Therefore, though a lifting gear at the breast end gives a little more chance of varying the conditions, it is by no means a necessity for an ordinary machine. By using the slices intelligently and getting the proportion of stuff and water correct, its absence will not necessarily be a disadvantage.

The behaviour of the stuff and water on the wire is a very interesting study. It will be found that in every case there are long fibres and fibrillæ, some of the latter so fine as to be nearly powdered. On emerging from under the slices, if the water is nicely proportioned, the long fibres fall to the under side of the sheet, and the fibrillæ remain for a time in suspension with the water. The action of the shake, contrary to what one might expect, keeps these fine fibrillæ suspended for a time, until they are sifted into the spaces between the longer fibres, and by the gradual drawing out of the water by the tube rolls they remain there permanently. As the stuff approaches the first suction box, the action gradually ceases, so that the suction sets the sheet without altering the disposition of the fibres. It seems to be a fairly general belief that the shake turns the fibres from their 'end-on' flow from the apron. But a simple experiment will show that this is a fallacy. Take a few matches and float them in a rectangular tray. Give the tray a sideways shake and the matches will arrange themselves broadside on to the direction of the shake. Close observation will show a similar action on the wire when the stuff is beaten rather raw and long. It must be remembered that the shake does not make a *flow*, but, what is quite a different thing altogether, a *wave*.

Actually, with a well-fibrillated stock, the longer (or any) fibres are not moved much, if at all, from their endways flow. Moreover, the end-on flow of the fibres from the apron is not so pronounced as is generally supposed. The passage under the slices tends to turn round fibres that are pointed endways, especially the longer and bulkier ones. These, being entangled with fibrillæ, will naturally remain very much in the position in which they emerge. If they do alter their position, it will be towards placing themselves end on, because the shake is forcing them to this position.

An examination of paper made with and without shake will show this to be correct. The increase in strength given by the shake is due to the fibrillæ being spread and sifted into what would otherwise be bare spaces, or air spaces, and making a uniform in place of a 'patchy' paper. If there is too little water with the fibres, the fibrillæ will not be so sifted, because their carrying medium is absent. If too much water, they will not have settled before reaching the suction box, but will still be in a suspended state. Then too much suction will have to be used, and the whole fabric of the sheet will be disturbed.

A long wire is not always an advantage in making strong papers. The extra water which is used and the extra time the stuff is under the influence of the shake give the shake more opportunity of bringing the fibres into an end-on position. Ledger and other strong papers made on a 50-feet wire have a more pronounced difference in breaking strain across and along the sheet than those made on a 40-feet wire, and it also is more difficult to give the sheet the characteristic look of strength combined with clear water-mark which is a feature of good ledger papers. If it is desired to give to a paper made from rather poor stock the *appearance* of strength, a deep dam behind the slices will cause the stuff to rush well up the wire and get very little result from the shake. It will then *look* strong because the dandy roll has no nice level surface to impress, and the fibres will be arranged in all directions, but it will have less strength than if made a closer-looking paper.

In trying to make a close, well water-marked sheet from stuff that is not well fibrillated, extra water and shake will be effective only up to a certain point. That point has been reached when the fibres are not settled into a compact body before reaching the suction box. Less shake may be tried, or if shake is known to be not above normal, less water is wanted.

Too much water and too little shake, or either alone, are shown by the formation of water drills. These are thin streaks made by the water running in channels along the wire and refusing to amalgamate with the stuff. More often too much water is the cause. But a wire that is dirty in streaks, or badly beaten stuff, will also give the same trouble.

Stuff that is beaten very fine—that is, very much *cut* by the beaters—is easily water-marked, and looks 'wet' on the wire, but is shown to be free when passing over the suction boxes. This style of beating and paper-making makes a very nice close sheet and a clear, bright water-mark, but the strength is very poor for the quality of the stock used. Water drills are very often prominent in stuff of this description.

It may be mentioned in passing that fresh water is more productive of water drills than the softened back-water of the machine; also, if fresh water has to be used to supplement the back-water of the machine, it is much more difficult to make a close sheet.

In making an engine-sized paper the slices have to be closer to the wire than would be otherwise desirable, in order to keep back the froth which forms on the breast of the machine. Very often with strong stuff, and with papers containing a large proportion of wood fibres that have been kept a good length in the beater, numberless clear specks and spots appear in the paper. These are caused by the chemical action of resin, alumina, hard water, etc., forming carbonic acid gas (CO_2). This formation of gas takes place on

the wire itself as well as before it. The little bubble of gas keeps the fibres from settling on the wire, and when it bursts, it is usually too far advanced towards the suction box for the hole to be closed up again. The remedy is to use as much water with the stuff as is possible, to fill the space again that has been made by the bursting of the bubble. Beating the stuff finer, or running at a slower speed, will also effect an improvement. Entrained air and other gases, sometimes caused by the chlor-lignins, also cause these froth spots.

Froth is often a great nuisance on the machine, and sprays should be provided to keep it down as much as possible.

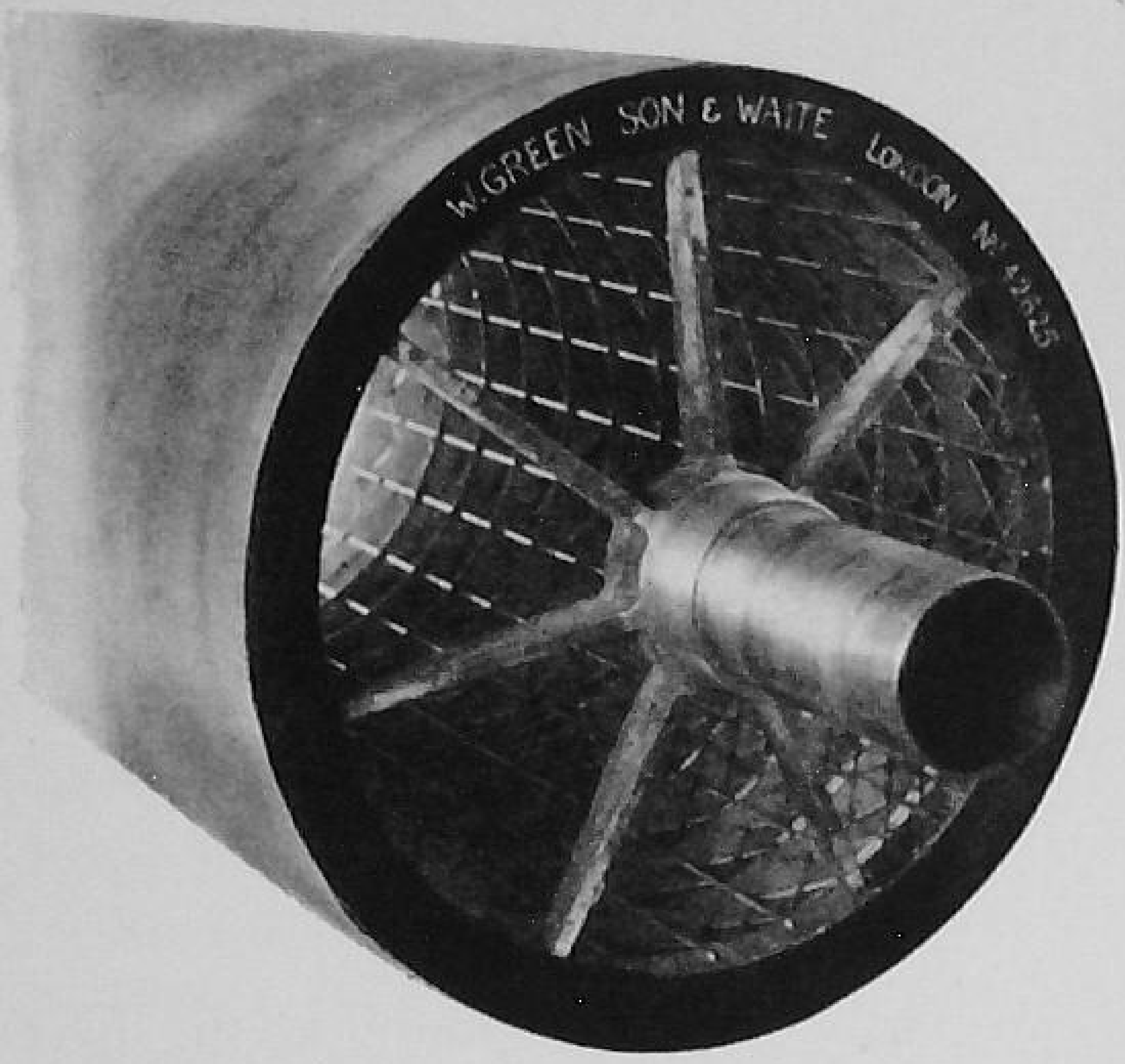
A little extra alum will sometimes be of great assistance, or a little paraffin run into the stuff from a tin above the chutes by means of a woollen thread, where this is otherwise permissible.

Steam Heating of Stock.—The effect of raising the temperature of the stuff and water on the machine is to make it work more 'free'. Advantage is taken of this fact when making heavy substances or running highly fibrillated stock. By raising the temperature to about 90° to 95° F. an extraordinary change in the working of the stuff on the wire can be observed. The fibres swell up and become more rigid, the meshes of the wire open a little owing to the expansion of the metal, and, chiefly important, the tenuity of the water is increased and its surface tension lessened. The effect of these things is that the work of the suction boxes, and consequently the strain on the wire, is made much less. More water and shake can then be used and a closer and more clearly water-marked paper can be made. The best situation for the steam-pipe is in the top-level water box. A stronger paper may be made from heated stuff than from the same stuff run cold.

The Dandy Roll and its Use.—The body of a dandy roll is a brass tube on which are fixed a number of brass discs and a framework of cross-wires. A cylinder of wire cloth similar in mesh to a machine wire is pulled over the body and fixed at the ends. This is called a 'wove' roll (Fig. 166). The centre tube is extended as spindles, which run in the bushes of adjustable brackets fixed at each side of the machine, between the first and second suction boxes or in a position found most suitable. A 'laid' roll (Fig. 167), instead of having a woven cover, has one made from parallel wires. These are kept apart and in position by twisted wires round the circumference, from ¾ to 1½ inches apart. These are called the 'chain' wires. Letters and devices of wire may be sewn or soldered on the surface of the roll.

Plate-laid Dandies.—For many years laid dandies were constructed in the same way as laid moulds, so far as holding the lay wires is concerned. The lay wires were held in position by two thin chain wires which were

twisted once between each lay wire, in the same way as has been done with laid moulds for hundreds of years. A few years ago, however, the plate-laid dandy was introduced, in which the plates or discs forming part of the framework of the dandy had holes punched around their periphery corresponding, in the number of holes per inch, to the number of lay wires required per inch in the paper. When all the wires have been threaded through the plates, and fixed at the ends, the plates are filed down by hand so that they stand as proud from the lay wires as is required for the chain line in the paper.



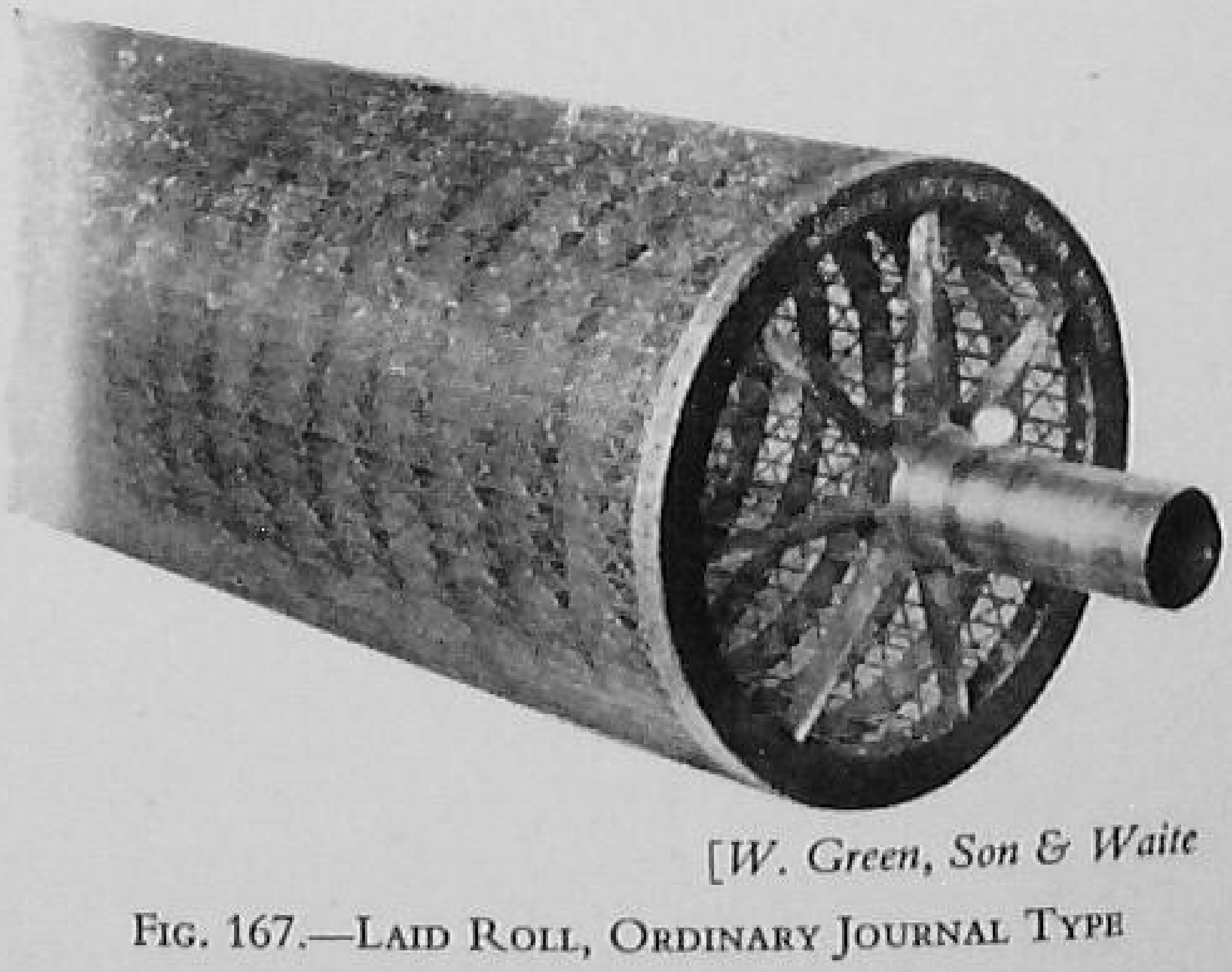
[*W. Green, Son & Waite*

FIG. 166.—WOVE ROLL

These plate-laid dandies have been used for a number of years on thin tissue papers such as cigarette paper, but they are now being adopted universally for the making of laid paper. They have several advantages over the chain line made from twisted wires in that they are not inclined to clog up with fibres, and they are much less inclined to 'pick'. They require a very high degree of craftsmanship in their manufacture, and in consequence they are expensive, but in every way they are to be recommended in place of the twisted wire chain line.

Two close-up illustrations, Figs. 169 and 170, show the difference between the twisted and plate method of construction.

Hollow Dandies.—Nowadays increasing use is being made of hollow-type dandies having no spindles or journals (Fig. 168). These are very rigidly constructed and have many advantages over the old type. In the first place they run on a rim supported by rollers on ball bearings on a special stand having a very fine adjustment (Fig. 171). The bracket which is illustrated also has a quick lift lever, enabling the dandy to be lifted clear



[*W. Green, Son & Waite*

FIG. 167.—LAID ROLL, ORDINARY JOURNAL TYPE

of the wire instantaneously. The fact that the dandy is hollow enables stationary steam- and water-pipes to remain inside the dandy and to be used continuously or intermittently for cleaning it from the inside. The advantage of this will be obvious. It is also possible to fit a stationary tray inside to catch water and pieces of stuff, and run them clear of the dandy.

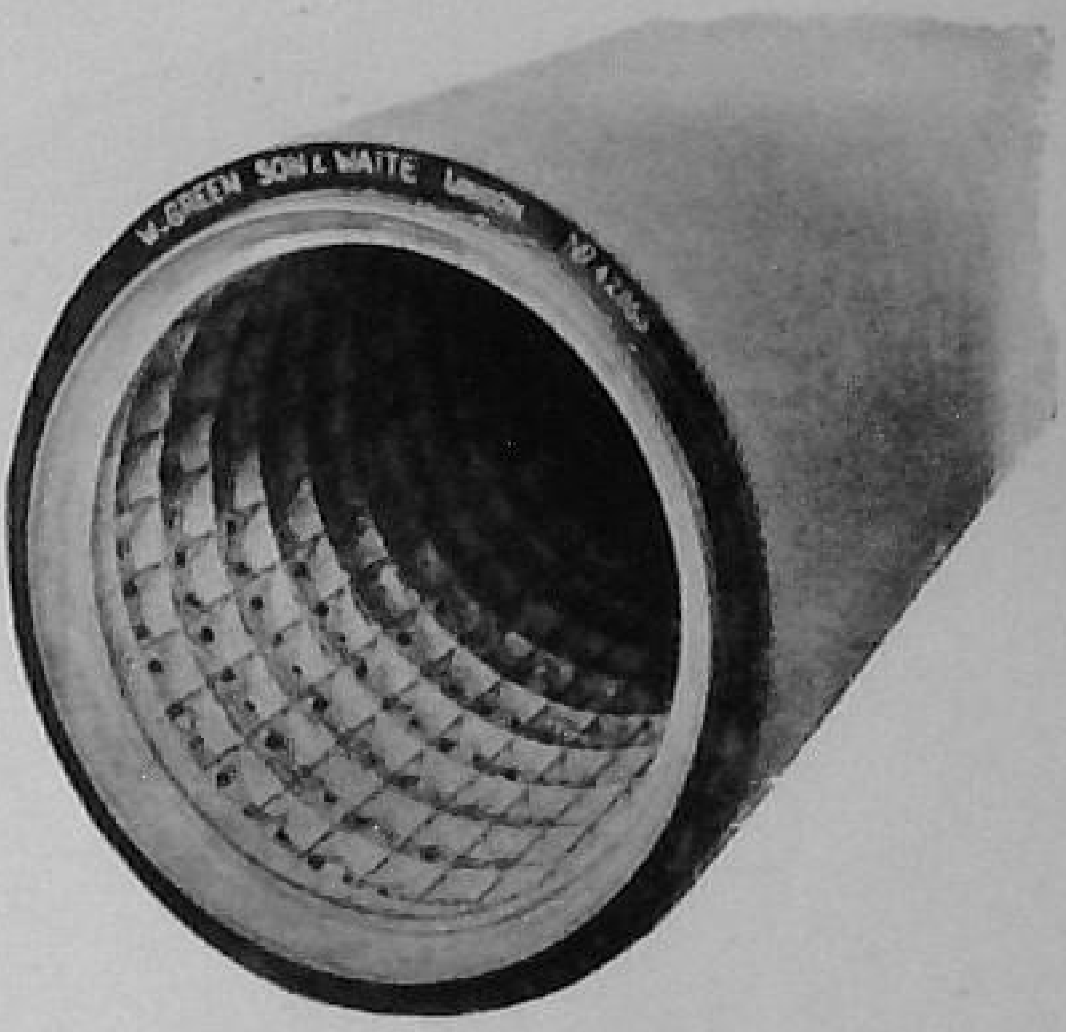


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FIG. 168.—WOVE DANDY ROLL, HOLLOW TYPE

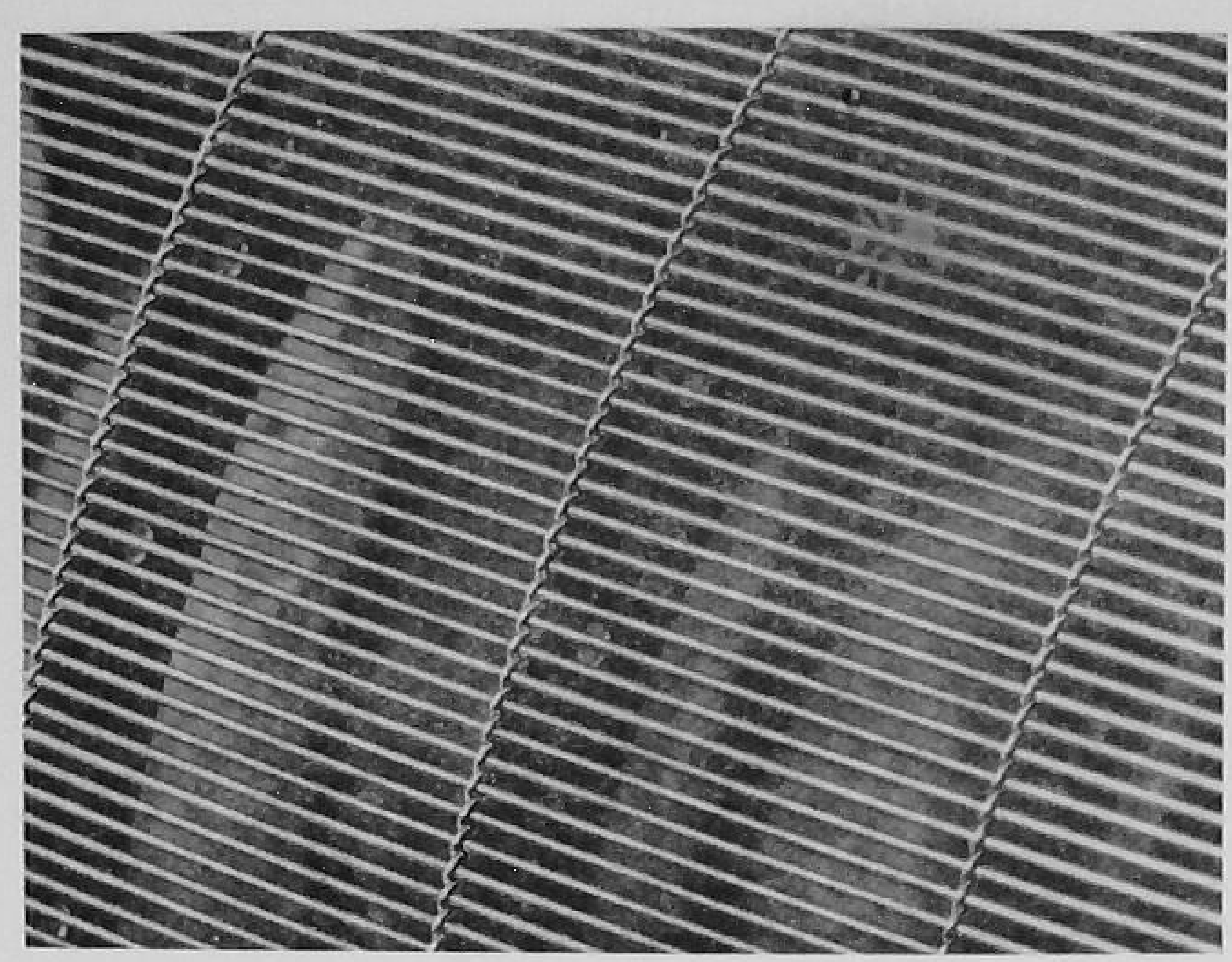
The introduction of these hollow dandies has enabled much greater speeds to be attained without deterioration in the quality of the paper, and it is possible to run these dandies for 6 to 8 weeks continuously without having to remove them from the machine for cleaning.

The function of the dandy roll is primarily to assist in closing up the sheet by pressure on the fibres while in a wet state. For this reason a roll as heavy and large as can be run on the substance should be employed. Where letters or devices are on the roll, and require to be spaced for registering accurately a certain size of sheet, the size of the roll has to be accommodated to the size of the sheet. The letter or devices, being raised above the surface of the roll cover, impress themselves on the stuff on the wire, and by making thin places where they touch, cause the design to be transparent when looking through the sheet.

This is called the 'water-mark'. The clearness of the water-mark depends upon a great variety of circumstances, among which the chief are the amount of water left in the paper after passing the suction box or boxes in front of the dandy; the quality of the beating; the quality of the fibres and their length; the weight and diameter of the roll; the thickness of the wire forming the letters or designs; the speed of the machine; the substance of the paper and the skill used in closing up the paper on the wire. Subsequent operations on the machine, and the finish, also affect the water-mark. The couch rolls and presses all contribute a little towards taking away the clearness, and so does a very high finish, which may go so far as nearly to obliterate it altogether.

The proper amount of water to leave in the paper to get a good impression from the roll is altogether a matter of experiment. The suction is altered until the desired result is obtained. If too much water is left, the paper is crushed by the dandy roll; if too little, the roll makes a faint water-mark.

Very fine stuff gives the best results in wove papers. The wires sink into the body of the paper without encountering any long or hard fibres. Well-



[*W. Green, Son & Waite*

Fig. 169.—Close-up View of 'Chain Laid' Dandy, showing twisted chain wires holding the lay wires in place

fibrillated stock is required for the good water-marking of thin substances. A good laid mark requires longer stuff.

The fine fibrillæ on the surface take the impression well and long fibres on the under side help to sustain the weight of the roll and prevent 'pick up'. Soft, fine fibres such as esparto are easily water-marked. The wires of a design on a small diameter roll stand at a more obtuse angle from the circumference than they do on one of greater size. This makes them have a 'digging-up' action, which is very apt to cause 'pick up'. The figures on a large roll fall on the wire with more of an impressing motion, and are also supported by a greater plain area, which helps to press the water through the wire and prevents it returning to the impression and filling it up again.

Trouble is sometimes experienced from air bells with a wove dandy. A stream of air or steam, impinging on the roll as it rises from the sheet, stops the trouble, but if froth bells are coming along the wire their source must be found and stopped; usually more water will stop them. A laid roll with the laid lines arranged spirally round the circumference is used occasionally for cheap papers to attain a higher speed, but it makes a poor water-mark.

When using a roll with letters or designs on a thin paper it will be found that the raised letters, etc., pick up fibres or bits of pulp, the size of which increases with each revolution, until they fall or are brushed off by the

machineman. These are termed 'dandy picks' or 'picks' and are responsible for a great percentage of broke in thin papers. A small diameter roll, or one

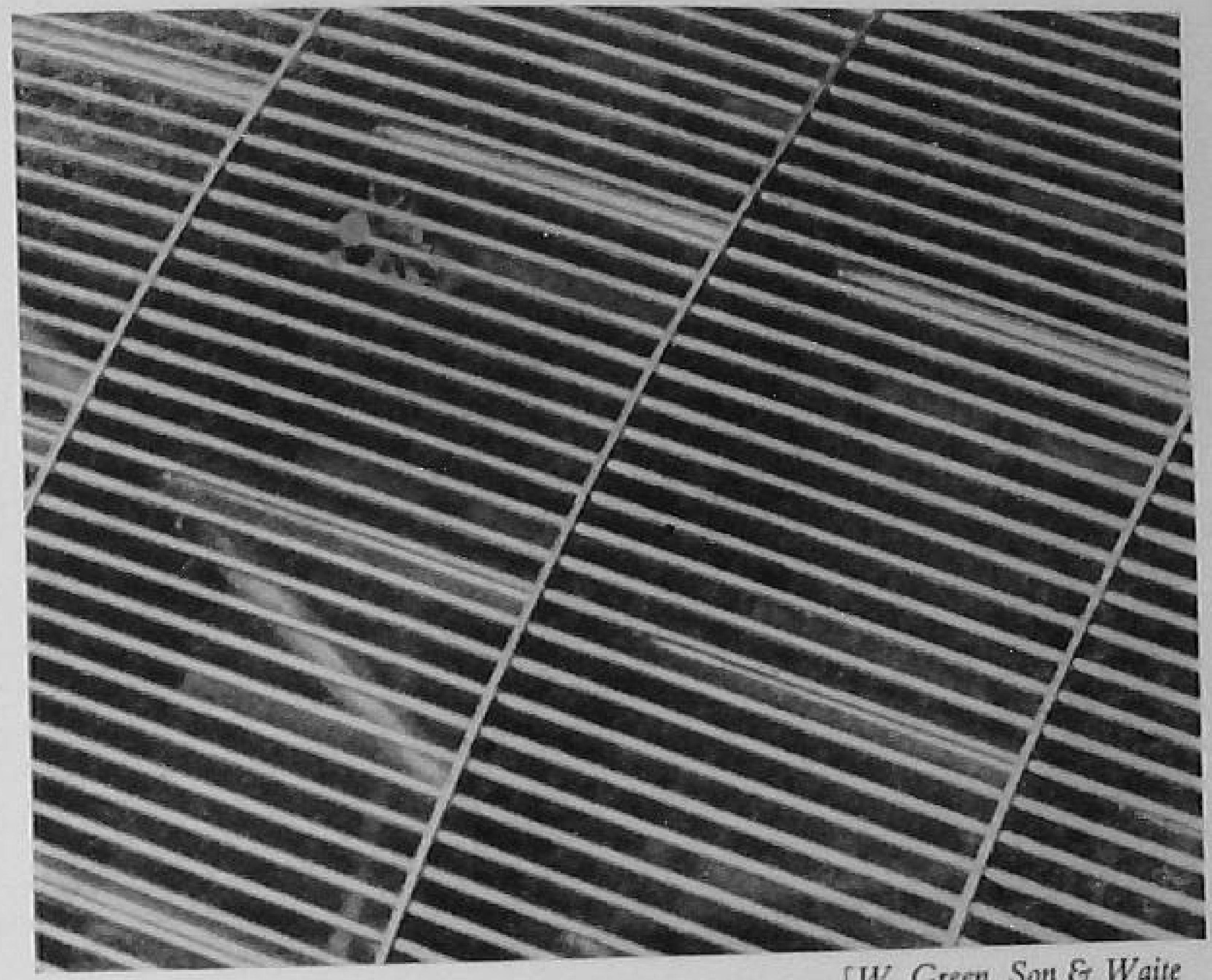


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FIG. 170.—CLOSE-UP VIEW OF 'PLATE LAID' DANDY ROLL, SHOWING LAY WIRES PASSING THROUGH THE PLATES

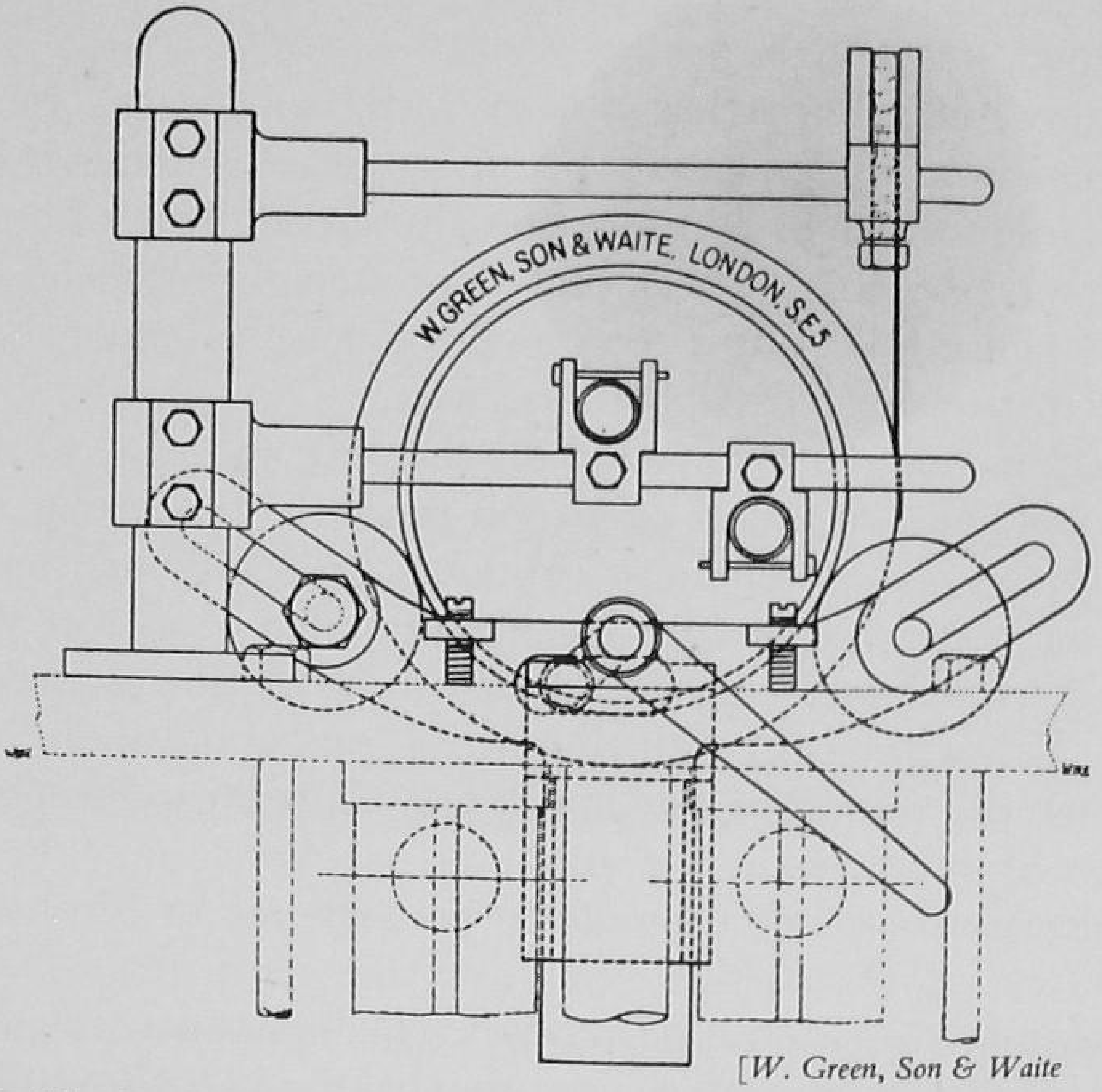
with heavy designs, gives most trouble. The remedy is to raise the roll carefully, so as to take as much weight off the stuff as possible without losing the clearness of the water-mark, or to reduce the speed of the machine, or to increase the length of the fibres, by altering the beating.

Therefore the character of the water-mark and the suitability of the roll have to be considered when trying to increase speed on a thin paper. An increase of speed is of no value if the proportion of broke from this cause is also increased.

A strip of old wet felt, called the 'wiper', is suspended by a rod over the dandy roll, and may be let down on it when running at a low speed. It is an excellent device for keeping the roll clean and free from 'picks', if it can be used. Wove rolls are liable to fill up with froth, when they have to be taken off the machine and washed out. Fine sprays of cold water are sometimes used on the roll to prevent the froth forming. A rubber roller running on top of the dandy will be found of great use in collecting the bits of stuff picked up by the dandy. This roller throws them on to a cloth fixed in front of the dandy.

Dandy rolls with designs that must register correctly have to be set in correct parallel across the machine to bring the designs square with the cut sheet. The draws or tensions between sections of the machine are used to

bring the water-mark correct with the cutting length or 'chop'. Often a roll will be found to be short in the draw, and after all the sections have been



[*W. Green, Son & Waite*

FIG. 171.—DANDY STAND, BEARINGS AND ADJUSTING MECHANISM FOR HOLLOW DANDIES

pulled tight the draw is still too short. A few turns of tape, or one turn of thin old wet felt round the ends of the dandy roll outside the deckle edge of the paper, will lengthen the distance between the designs, and it is more prudent to do this than pull up the sections too hard. If the wiper can be used, it will give a fraction of an inch more length by slightly dragging the roll. The register of the water-marks across the roll is more difficult to alter. On narrow deckles (up to 60 inches) they are seldom far out, but on wider sheets, such as four or five sheets of 16½ inches, the beating and quality of the fibres may alter the shrinkage by as much as 2 inches. The beating of the stuff must then be altered to bring the width into register with the roll. If the draws can be altered the width may be controlled a little, so that by putting a turn or two of tape on the roll the length may be brought out and the draws put back, which will give more space between names across the roll.

When ordering a new roll, the makers should be made aware of the quality for which it is to be used, when they can produce a roll with the water-mark spaced to register very correctly.

Extra weight on the couch and press rolls will prevent shrinkage on the drying cylinders to some extent; so also will tightening up the dry felts, but in these cases the shrinkage is apt to take place later—that is, on the dryer after tub-sizing.

A laid dandy roll is more tricky to deal with than a wove. It is customary to have a small tube roll or a soft brush set exactly under the roll. This allows a little more water to be used after the suction box. The tube roll or brush takes away the extra water that is pressed through the wire by the weight of the dandy roll. But if too much water passes under the roll, it will 'lift' sections of the sheet partly off the wire.

These sections may be even lifted off the wire and stick to the roll for a few turns, when they come off and spoil the wire by passing through the couch rolls. If a good water-mark cannot be got without this happening, the make of the paper on the wire must be attended to. More shake and, if necessary, more water are required, so that more suction is used on the first suction box. This will ensure that the sheet is pulled down on the wire with more force than the weight of the dandy roll can exert to lift it up again.

A little manipulation of the tube roll or brush may be all that is necessary, but care must be taken not to raise the roll or brush so high that the wire is lifted off the suction boxes, or that the paper is made to look streaky. All dandy rolls should be allowed $\frac{1}{8}$-inch play between the brackets, so as to allow for the slight movement of the shake, and to prevent them being dragged.

Dandy rolls being very delicate and expensive, too much care cannot be expended on their use and storage. They should be carefully washed out by means of a good jet of water when they are taken off the machine. If they are left standing for some time, while the machineman does something else, the frothy matters in the meshes will quickly dry up, and be very difficult to get rid of. Indeed, it is sometimes impossible to clean them without using strong acid, which is the worst possible enemy of the dandy roll.

A machineman who neglects to wash out and thoroughly clean a dandy roll immediately on taking it off a machine does a grave injustice to his employer and to his shift mates, who will perhaps be compelled to take drastic means of cleaning it before it can be used again. In any case, every machineman should carefully examine the condition of a dandy roll before he puts it over the wire, and report to his foreman any damage it may have received.

Very light hollow dandies are now available, which weigh only about one half as much as the rolls which were in use only a very short time ago. Lighter metals are used and also a very much simplified framework, which is, however, very strong and rigid. The brass laid wires are rapidly being

replaced by wires of stainless steel, which give a better laid mark, do not pick so much and are very much stronger.

For wove rolls monel metal wire cloth is now in use in place of phosphor-bronze cloth, and gives less 'streaking' at high speeds.

Besides the dandy cloth, very light rubber-covered rollers are sometimes used and run on top of the dandy, to remove 'picks' from the surface of the roll and stop them going round several times, until they pick a hole in the paper.

There are several types of dandy drive available both for spindle dandies, and also for driving hollow dandies, through a belt on the rim. These drives are a combination of an electrical and mechanical drive. One in general use in America is made by Spencer, and Metropolitan-Vickers and British Thomson-Houston make them in England.

When the web has passed under the dandy roll the paper is made. Subsequent operations are simply water extraction, with the minimum of damage to the bulk and water-mark and the elimination of felt and wire marks. Finish on the machine is a question of moisture, pressure and number of rolls used, and practical experience and experiment on the part of the machineman. Moisture content is controlled by the drying operation, and this again by the steam heat admitted to the drying cylinders. Several systems may be used by the dryerman. A certain pressure may be admitted to several or all the cylinders and controlled by the main valve; or he may use the cylinders separately, admitting more or less pressure, according to the feel of the paper, without altering the main valve. The third and best way is to keep the pressure constant by using the main valve and to make finer adjustments separately on each cylinder.

The heat of the cylinders should be so graded that the paper gets no sudden heat, but is gradually raised in temperature as it travels towards the dry end.

It is very difficult to get and keep a regular finish on a paper-making machine. There must be a certain quantity of moisture left in the paper before it enters the calenders, and the condition must be the same all across the sheet. Any unequal pressure of the couch and press rolls, worn and damaged wet or dry felts, dirty or corroded places on the drying cylinders, unequal spread of the stuff on the wire or ridges in the latter will affect the moisture content of the paper and show up in the finish.

A change in the beating from wet to free, or vice versa, however slight, changes the conditions of the pressing and drying and upsets the finish. Constant attention and good clothing are necessary if the finish is to be kept accurate and constant to the sample.

Great care is required when using steam-heated rolls, as heat affects the camber, sometimes expanding the ends of the rolls more than the centres. It is best to heat the rolls thoroughly before starting the machine.

When the paper is put through, the result will enable the machineman to alter the heat, or put on more or less pressure to get a level finish. If the rolls are not heated in time there will be the greatest difficulty in heating them afterwards, owing to the cooling effect of the moist paper. As calender rolls are cambered to a certain pressure, any pressure over or under that point will cause uneven finish across the sheet. If the finish is not correct with the pressure intended for the rolls, the spread of the stuff on the wire must be slightly changed to suit the pressure required. Thus if an unequal spread gives a finish too high in the centre, by putting down the slice in the centre of the wire the paper will be slightly less in substance and will come along the machine dryer and take less finish. Too much pressure on the calender rolls, even when well cambered, gives high finish at the sides and low finish in the centre, because the rolls are sprung on the centre. This seems incredible with steel rolls of the usual diameter, but can be easily proved to be correct by experiment.

When an equal finish across the web cannot be obtained, the spread of the stock on the wire should be looked to. Too much pressure on the coucher and press rolls will make the edges of the web too dry, because these rolls also are cambered to a certain pressure and spring in the centre.

A badly worn felt which is most worn in the centre gives a high finish in the centre and low finish at the edges, owing to the edges pressing the paper against the cylinders harder on the edges than in the centre, this giving an unequal moisture content. Constant attention is required to keep the finish correct; when the exact finish is obtained the attendant should note the position of the carrying roll over which the web passes after leaving the cylinders. The spring will be found to tighten up when the paper is too dry, and to slacken off when it is too moist.

The average position should be noted, and if necessary marked, and the least change in moisture content will be quickly apparent. Another good guide is the amount of steam coming from the last dry felt as it leaves the paper. When altering the speed of the machine or the substance of the paper, the man in charge should always tell his assistant so that he is not taken unawares, but can shut off or put on steam beforehand.

Water-Marking.—The water-marking of paper is carried out in two distinct ways, depending on whether the paper is hand-made or made on a Fourdrinier machine.

In the case of hand-made paper, the design is formed on the wire cloth

of the mould by sewing or soldering designs or letters in wire upon it. When the mould is immersed in the stuff, the wire designs or letters cause a thin place in the stuff, and this appears as a transparent place in the finished sheet.

A variation of this effect may be achieved by pressing or countersinking a design into the wire cloth, and in this case a thick place is made in the stuff—that is, more stuff is deposited there—so that a dark or thick mark appears in the finished sheet. A combination of thick and thin places may be produced on the same sheet and very fine effects may thus be obtained.

The water-marking on some currency and bank-note papers made by hand, and also on the machine, is very beautiful, and requires a high degree of skill on the part of the wire-workers who make the moulds.

The second method of water-marking is that used on the machine, and it differs from the previous one in that the impression is made on the web after a good deal of the water has been removed and the web has become settled in place on the wire. It is carried out with the aid of a wire-covered skeleton drum made of brass and supported in brackets fixed to the wire frame. These brackets have a fine-adjustment screw, so that the drum or dandy roll, as it is called, may be very finely adjusted upon the surface of the stuff. The roll is always placed after the first or second suction box, so that the amount of water left in the web when it reaches the roll may be regulated.

It is in the careful and skilful manipulation of the water in the web when the dandy roll touches it that the best results may be obtained, for if the web is sucked too dry, no mark will show, and if left too wet it will be crushed and 'worms' or 'tears' will appear in the sheet.

The dandy roll performs two distinct functions. First, it closes up the sheet, compressing the fibres together and generally improving the appearance or look-through of the paper, and for this purpose it is not necessary to have any design upon the roll; and, second, it is used for putting a name or device into the paper. In a plain 'wove' roll the skeleton drum is covered with fine wire cloth similar to the machine wire, and this roll does not actually water-mark the paper, but simply closes it up. Very high speeds may be attained on 'news' machines, using a plain wove dandy, provided the roll is of sufficient diameter and of correct weight and construction.

A different type of roll, and one used chiefly on ledger and thick writing papers, is known as a laid roll (Fig. 167). This roll, instead of being covered with wire cloth, is covered with a collection of thick brass wires bound together at intervals of an inch or so by fine wires. Various gauges of wire are used, and thus the number of wires to the inch may be varied to suit the thickness or other characteristics of the paper. The thicker and stronger the

paper, the coarser the wire used and the fewer the number of wires to the inch. Azure or blue papers look better with fewer wires to the inch than cream papers. A medium substance of ledger paper usually has about 18 wires to the inch, a writing paper about 20 wires and a thick, strong ledger about 16 wires. On fine tissues there may be from 30 to 40 lay wires per inch.

Water-marking by means of a dandy roll is done by fixing a device or letters worked in wire on the cover of the roll, and this may be done on either a wove or a laid roll. The device stands out from the surface of the roll, and the weight of the roll presses the wires into the soft wet web, forcing the fibres away in all directions and compressing the other fibres, and thus forming a thin place in the web. When paper marked in this way is held up to the light, the device shows up as a translucent pattern.

Formerly, water-marks served as trade-marks for mills making the paper, and to a certain extent this still holds good, although probably the greater number of registered water-marks nowadays belong to the whole-sale stationers and printers. Some well-known devices are show in Fig. 172. The marks vary from simple words of a few letters to the most elaborate and artistic designs—coats of arms, ships at sea, etc. Some very fine water-marking is done on papers for postage stamps and bank-notes, and, generally speaking, the finer and more intricate the design the slower the speed at which the paper has to be run. Many rolls containing intricate designs, and especially those having small round spaces enclosed by wire, are very troublesome on the machine, owing to the fact that they pick small pieces of stuff out of the web, causing holes to appear in the finished sheet.

Many water-marks have to register in the finished sheet—that is, they have to fall in a predetermined position in every sheet when it is cut and ready for use. In order to achieve this the dandy rolls have to be made to suit different sizes of paper, so that they vary in circumference and also in the spacing of the names across the roll.

The devices are either sewn or soldered on to the cover after being made separately, and when they are in position on the cover, all connecting wires used to hold the letters, figures or designs in place have to be removed. The designs are generally soldered on to the cover, and this is done by tinning the whole device before placing it in position and then running a soldering iron over it, causing the tin to run down and fix the wires to the cover.

Since the web of waterleaf is drawn out in length—that is, in the machine direction—during the time it passes from the wire until it is dried, it will be obvious that the distance between the devices *round* the roll will have to be less than the distance desired in the finished sheet, and as the web shrinks in

the cross direction, the devices will have to be spaced out further across the roll than they are to be in the finished sheet. These variations must therefore be allowed for when ordering a roll for any particular size of paper. The

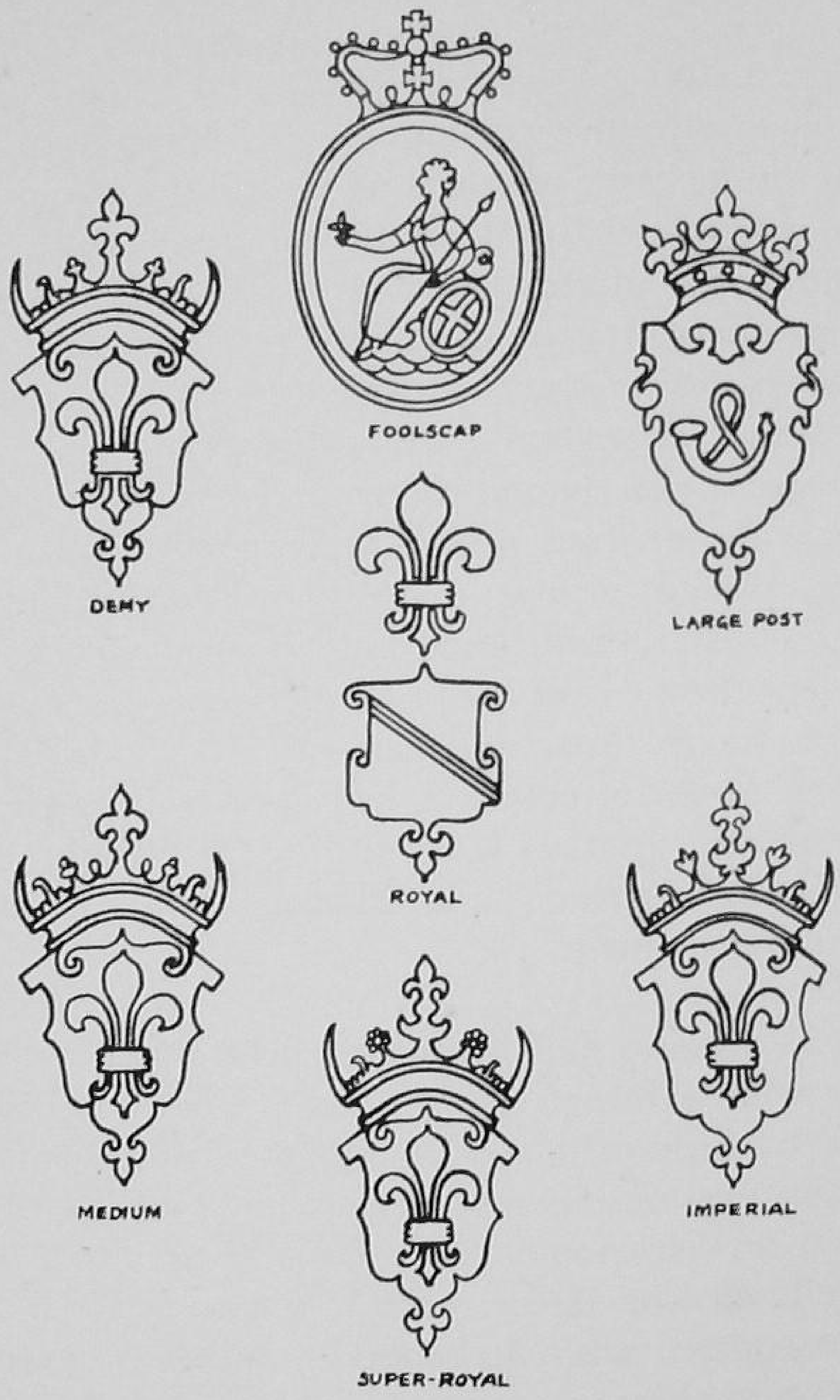


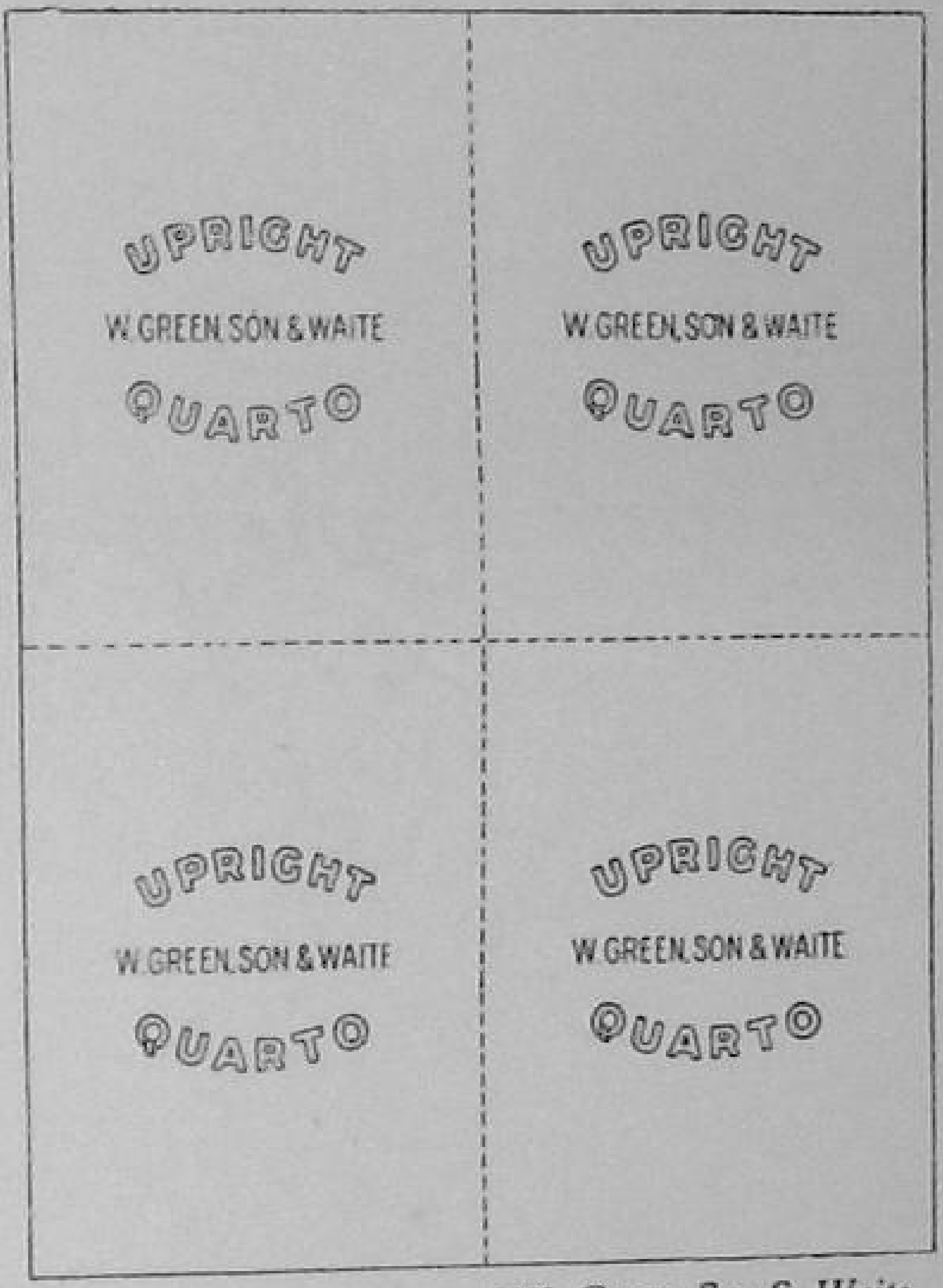
Fig. 172.—Water-mark Devices used in Certain Sizes of Sheets

variations remain fairly constant for each machine, but depend, of course, upon the 'draws' from the couch roll and presses, the heat of the first set of drying cylinders, and also on the nature of the stuff.

A roll for water-marking a sheet of Large Post, made $16\frac{1}{2}$ inches across the machine, will have to be about $20\frac{1}{4}$ or $20\frac{1}{2}$ inches in circumference and the names will be spaced about $17\frac{1}{8}$ inches apart; this will allow

for a stretch of about $\frac{1}{2}$ to $\frac{3}{4}$ inch down the machine and a shrinkage of about $\frac{5}{8}$ inch across the machine for each sheet.

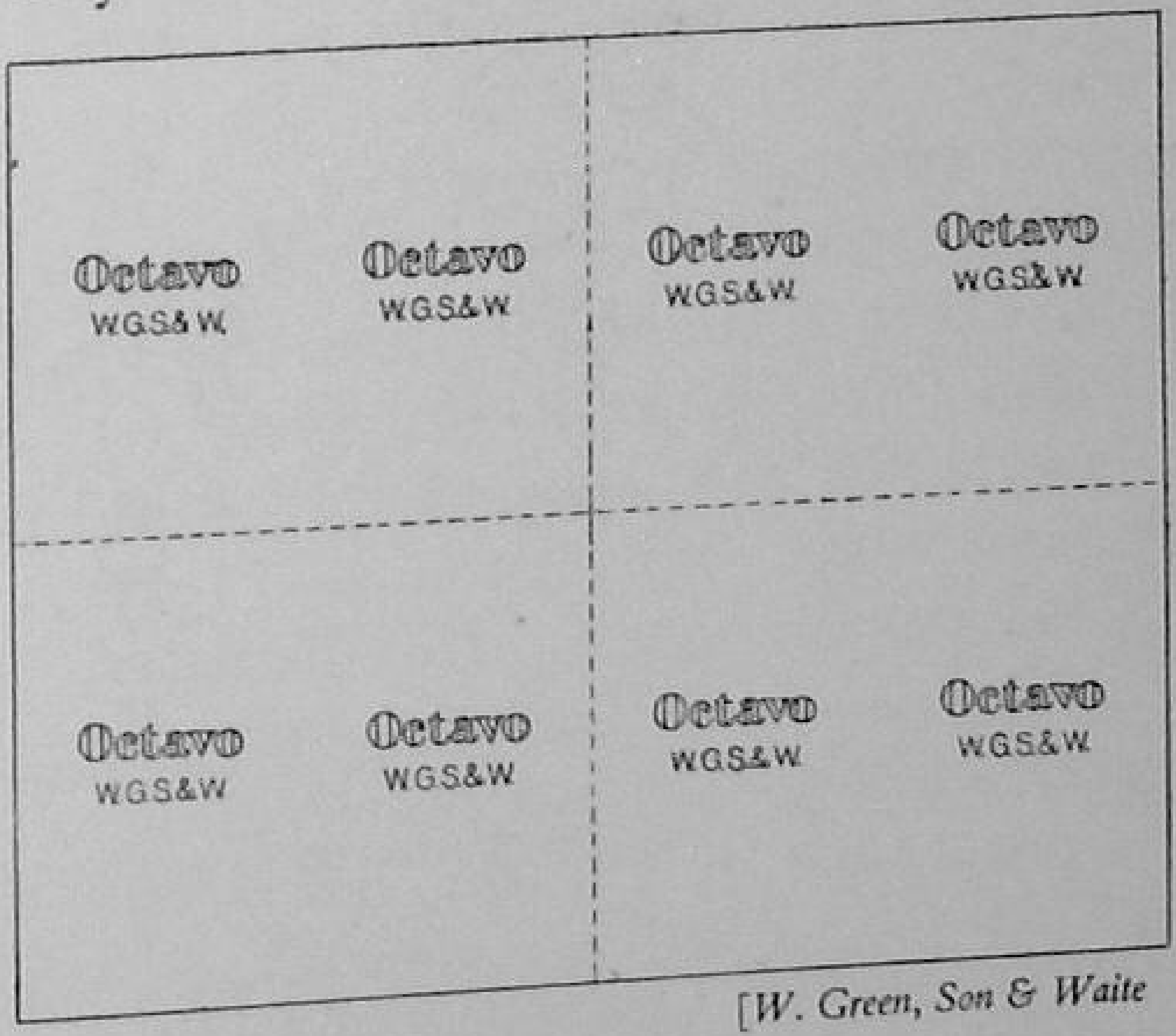
Figs. 173 to 176 show the positions of the water-marks in a sheet of writing paper.



[*W. Green, Son & Waite*

Fig. 173.—Showing how the Water-mark falls in a Large Post Upright 4to Sheet, 4 on

Unless these matters are attended to and the 'draws' carefully regulated, a great deal of broke will be made at the cutters, on account of the name or design not appearing at the correct and regular interval in the finished sheet. With papers for postage stamps and currency notes, where the water-marks have to register exactly and correspond minutely with intricate printings and perforating, special cutting marks are placed on the dandy roll, and the distances between these must be frequently checked by the machineman, at least after each beater is emptied, in order that any slight variation may at once be rectified by altering the draws or 'hanging' or lowering the dandy.



[*W. Green, Son & Waite*

Fig. 174.—Showing how the Water-mark falls in a Large Post 8vo

If the marks are coming too close, the dandy may be 'hung' or raised a little by lifting the brackets so that it drags on the stuff, or if the marks are too far apart the roll may be let down into close contact with the stuff. Except in the case of driven dandies the roll is driven round entirely by the friction of the stuff, so that the amount of impetus given to it may be varied by the two methods mentioned. A third way of increasing the drag upon it is to hang a felt cloth on it from above; this acts as a brake and reduces its speed.

None of these methods of 'dragging' the dandy roll is to be recom-

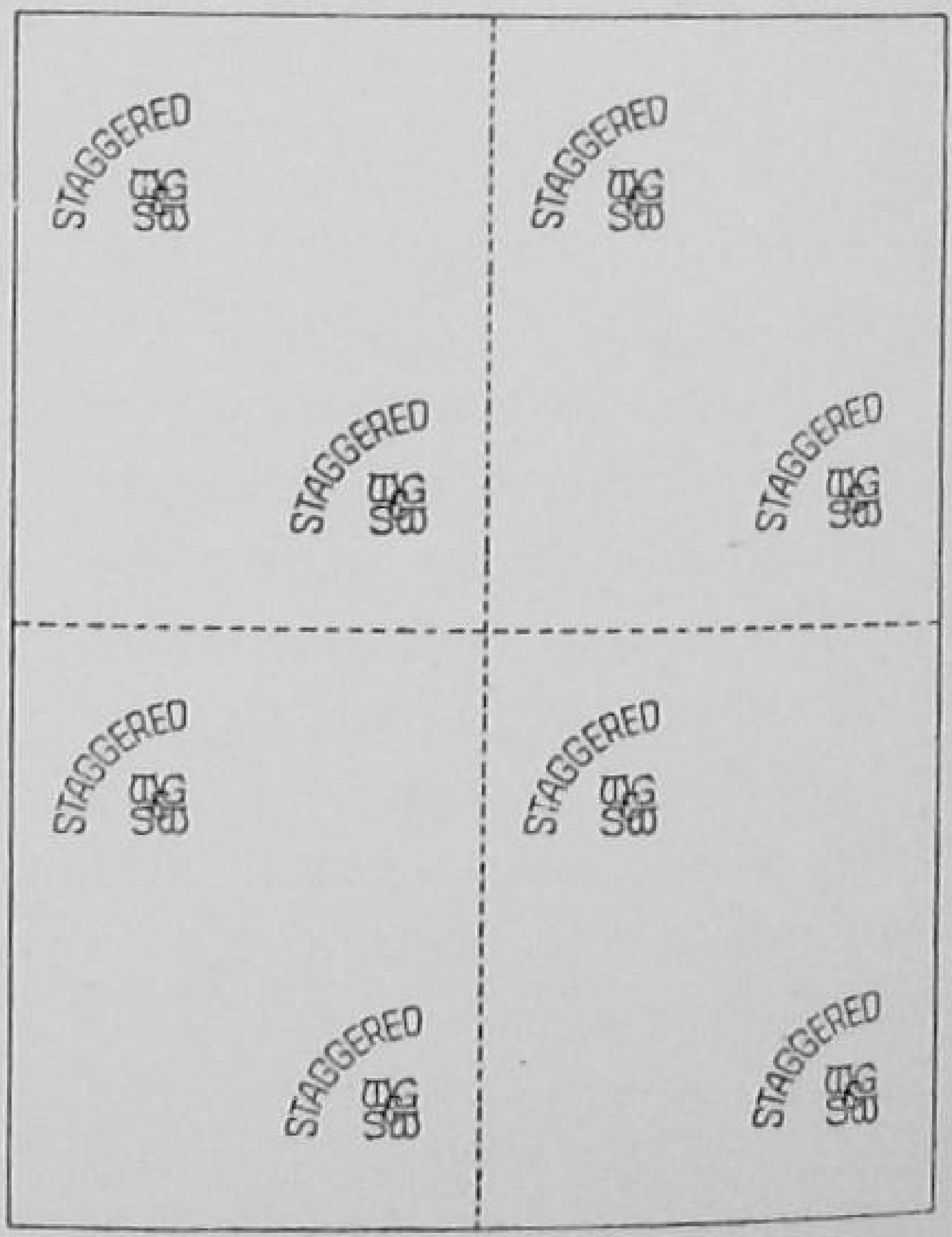
mended. Both are inclined to cause 'pick-ups'. A far better way is to run a turn or two of tape round the ends of the roll. This will give a more regular distance, and if the paper is of thin substance will take the driving of the roll off the stuff a little and prevent 'pick-ups'.

[*W. Green, Son & Waite*

FIG. 175.—POSITION OF WATER-MARK IN BROAD QUARTO SHEET

Dandy Drive. — Paper-makers have waited many years for one piece of equipment for which most firms have been very impatient, but which no one seems to have been able to bring to perfection up to the present time. This piece of equipment is the dandy drive, and although very many attempts have been made, mostly in mills themselves, to drive the dandy mechanically, none of them seems to have been really satisfactory.

With the advent of the sectional electric drive there would appear to have been little or no difficulty in arranging to drive the dandy in just the same way as the other sections are driven, by variable speed motors, but there seems to have been some difficulty in persuading the manufacturers of electrical equipment to tackle the job and give the paper-makers exactly what they want.



[*W. Green, Son & Waite*

FIG. 176.—POSITION OF MARK IN STAGGERED QUARTO SHEET

In America one or two successful attempts have been made to produce a dandy drive which works electrically and mechanically, but this has usually only been applied to spindle-driven dandies, whereas paper-makers require the drive not only for spindle-driven, but also for hollow dandies which have to depend on a belt pulley at one end, and it may be that in order to get satisfactory results the construction of the dandy itself may have to be altered. It is to be hoped that if this alteration

in construction is found necessary, it will not at the same time be necessary to increase the weight of the dandy.

It has been shown, especially on slow-running machines, that vastly improved sheet appearance and much more distinct water-marks may be obtained when the dandy is driven slightly faster than the wire.

When the dandy roll has to depend entirely on the friction of the stuff on the wire to drive it, there is bound to be slip and skids, and the dandy must obviously run at a slightly slower speed than the wire, and thus cause slight smudging of the clear look-through of the paper, and also of the water-mark, and this effect is intensified at higher speeds.

One method used in America was perfected in a paper-mill, and consists in driving a small generator from the couch shaft, and then passing the current generated across to a motor which drives the dandy through a P.I.V. gear box by means of a chain. This method has proved quite satisfactory at comparatively slow speeds on expensive water-marked papers, but little or no success appears to have been achieved by it on thinner papers at high speeds. At the present moment the British Thomson-Houston Company, of Rugby, and also the Metropolitan-Vickers Electrical Company, are both making dandy drives which have a speed variation which can be altered at will by the machineman, and it is hoped that these will be the answer to the paper-maker's request for some means of having very fine control over the speed, and the amount of weight placed by the dandy on the sheet.

THE M.G. OR YANKEE MACHINE

THE M.G. machine (Figs. 177, 178, 179 and 180) is a modification of the Fourdrinier machine, designed to produce papers having certain distinctive characteristics as to surface.

The single-cylinder (or M.G.) machine is so called because it usually has only one drying cylinder in place of the tiers of cylinders arranged on Fourdrinier machines. It is sometimes called a 'Yankee' machine.

The wet end is exactly the same as that of the ordinary Fourdrinier, having chests, sand-tables, strainers, wire part, couch rolls and—in the case of ordinary machines—press rolls as well.

When the web leaves the press rolls it is led on to a felt, called an over-felt, usually of special make, and this felt leads it into a nip between the large drying cylinder and a press roll or press rolls. The pressure exerted at the nip causes the wet web to stick to the polished surface of the hot cylinder, and it passes round the cylinder to the reel.

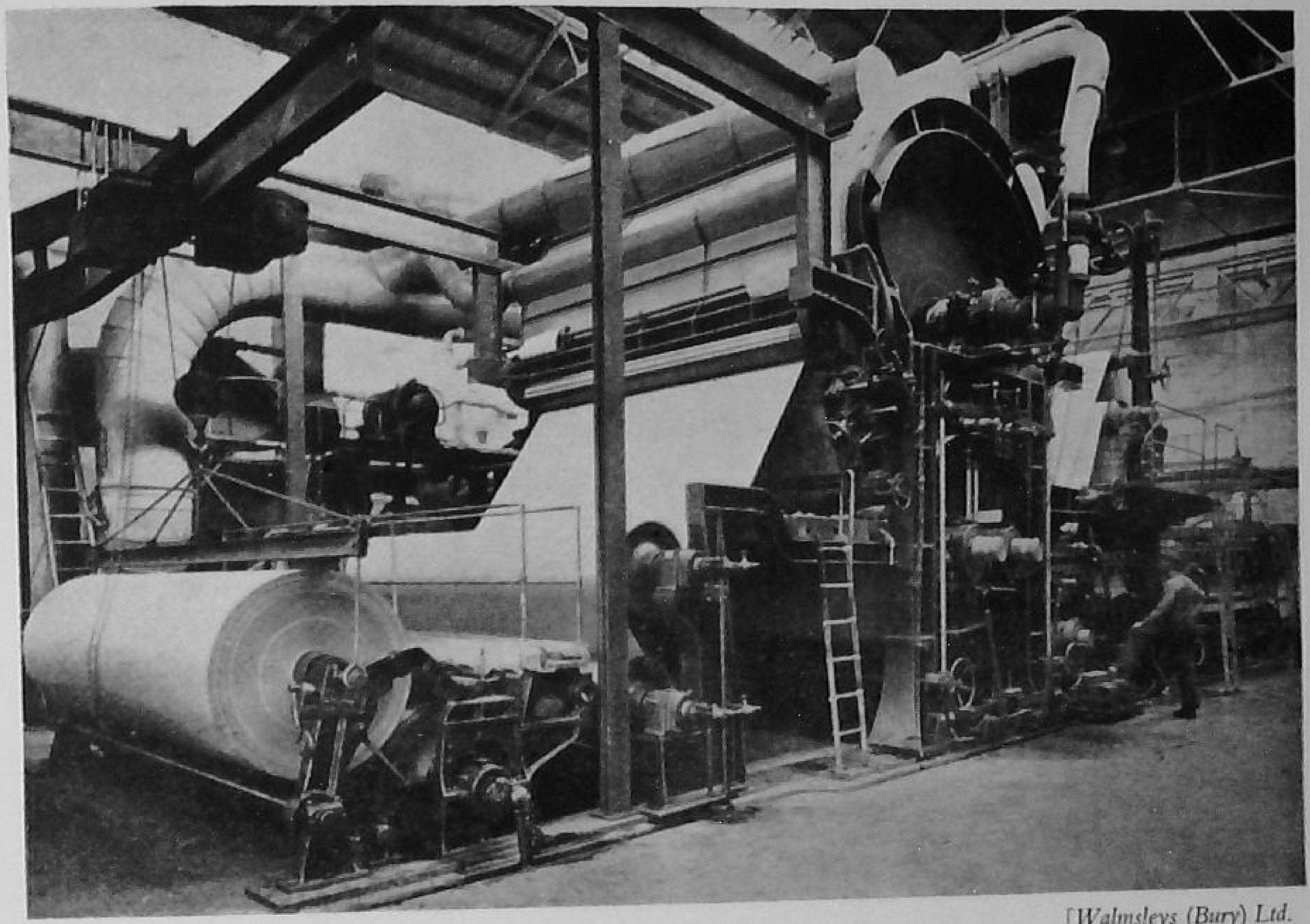
The cylinder is the most important part of the machine, is made of cast iron, or a mixture of iron and steel, chromium, etc., and is from 8 to 15 feet in diameter. The surface must be entirely free from blemishes of any kind if perfect paper is to be made, as any holes or depressions or flat places will seriously affect the surface of the paper. It should also be capable of taking on a good 'skin' or surface to which dust and fluff from the web will not adhere; or if it does adhere, should clean easily at the doctors.

The cylinder must at all times be absolutely clean and smooth with a mirror-like surface if a high finish is to be imparted to the paper.

These large cylinders are no doubt very difficult to cast, but a really good one is worth almost anything to the mill which possesses it.

On most machines the cylinder is fitted with a hood or cover, which fits closely round the surface of the cylinder for about three-quarters of its circumference. Under this hood there are, on some machines, a series of steam-pipes so placed that they are very close to the web of paper as it passes round the cylinder. Dry steam passes through these pipes and heats the moist vapour which is being driven from the web of paper by the heat of the cylinder. This assists the web to part with its water, and the vapour is drawn away from the hood by means of a large pipe and fan which exhaust it to atmosphere.

On other machines the hood has no steam-pipes, and the vapour is exhausted to atmosphere by means of a fan only. The process is really



[Walmsleys (Bury) Ltd.

FIG. 177.—M.G. MACHINE, SHOWING EXTRACTION PLANT FOR REMOVING THE MOISTURE-LADEN AIR FROM THE HOOD; ALSO COOLING ROLLS AND REEL-UP

vacuum drying except that the vacuum is very low owing to there being no sealing of the joints between the hood and the cylinder.

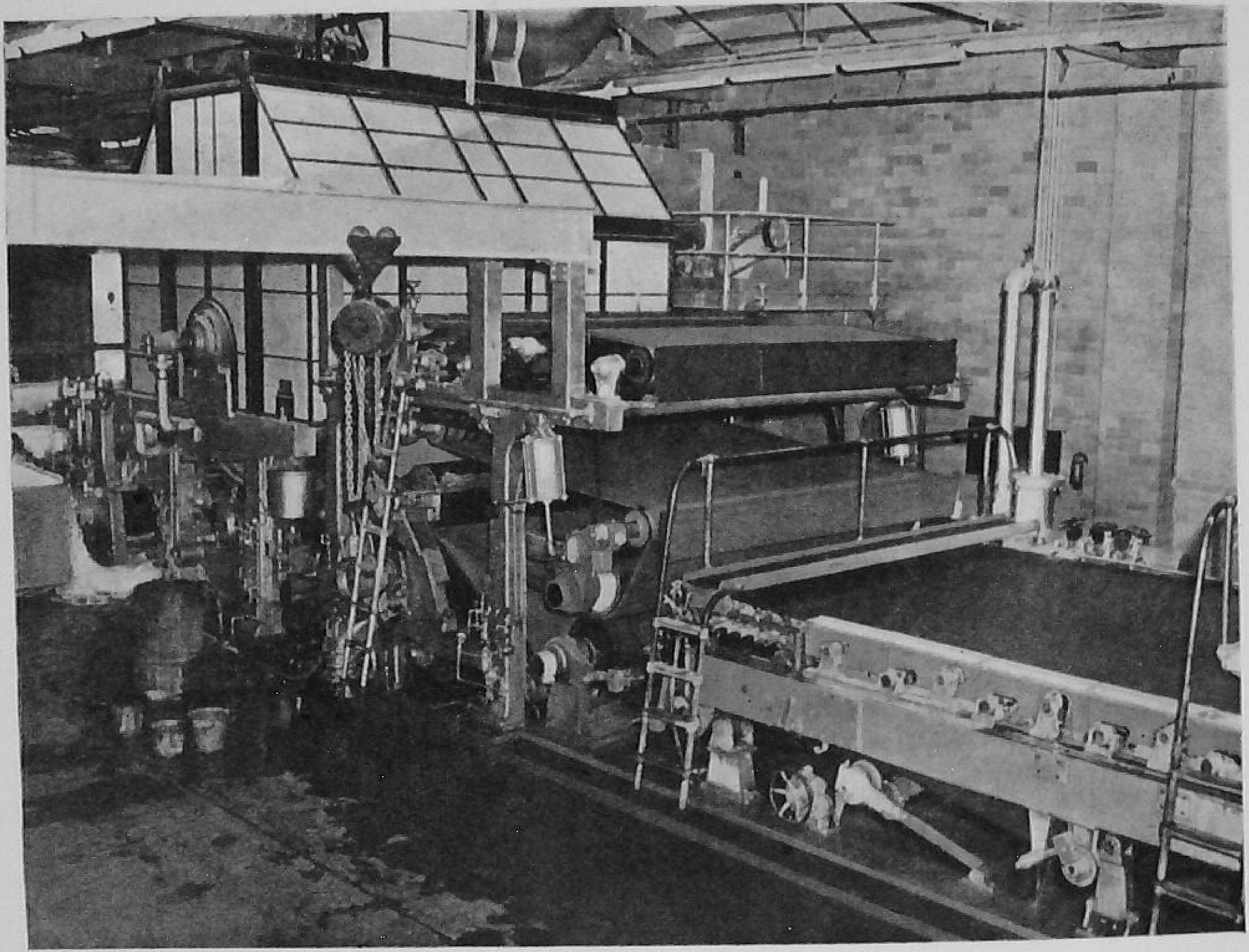
There are two distinct methods of drying the web on these machines, which have a marked effect on the finished paper, both as regards under side and surface.

In one method the top side of the paper—that is, the side farthest away from the wire and wet felt of the machine—is brought in contact with the surface of the cylinder. In order to effect this, the web has to be led round the cylinder in such a way that it finishes up at the front top of the cylinder nearest the wet end of the machine, and immediately above the press rolls.

This method obviously gives the smoothest surface and the roughest under side.

The other method consists in leading the paper from the press back into contact with the cylinder—which is revolving clockwise or in the same

direction as the wire—and in this case the *under side* of the web comes in contact with the cylinder and receives the smooth finish.



[*The Bagley & Sewall Co., Watertown, N.Y.*

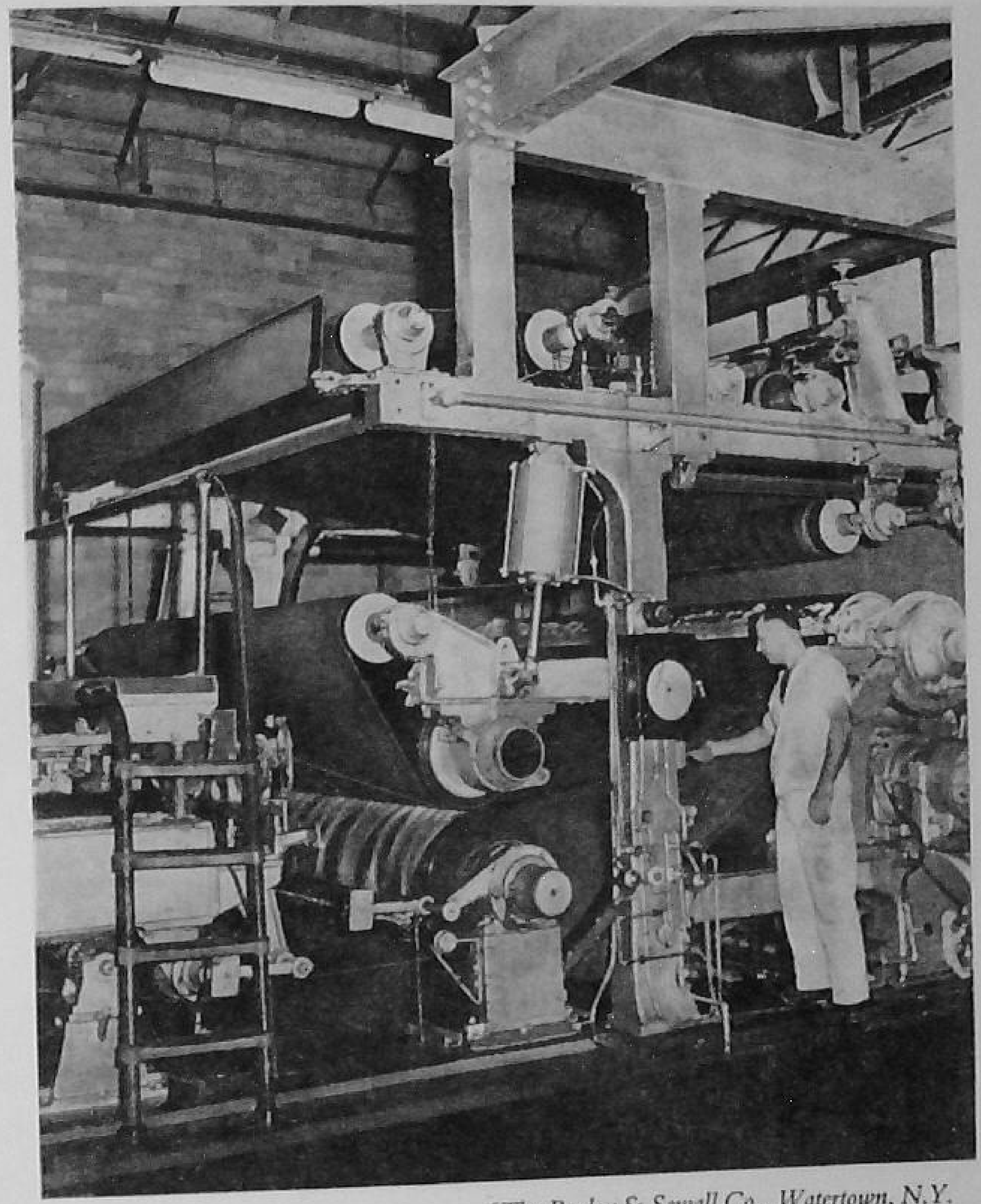
FIG. 178.—QUICK WIRE CHANGE WIRE PART, LICK-UP, AND DRYING CYLINDER OF HIGH-SPEED TISSUE MACHINE. THE CYLINDER IS FITTED WITH CRÊPING DOCTORS

This quick wire change Fourdrinier has cantilever arms extending from the back side of the Fourdrinier to permit raising the front side, and the couch roll is also raised at the same time. Two carriages carrying the draped wire are then pulled by a winch towards the machine moving the wire in place. Wire carriages are run back and the Fourdrinier and the couch roll lowered to original position. The Fourdrinier frame is then returned to operation position.

The result of this method is that the under side of the paper, though 'finished', has not the close and highly polished surface of the paper made by the first method.

In order to modify the effects of these two arrangements and to suit the particular paper to be made, recourse is had to felts of various qualities. These felts, used to carry the web through the cylinder nip, are called 'over-felts', and may be had either rough, smooth, thick or thin, ribbed, striped or plain, according to the effect it is desired to produce in the finished paper; they are made of wool. The finish obtained depends on a variety of circumstances, but chiefly on the surface of the cylinder, as has been stated above.

The press roll which squeezes the web into contact with the cylinder is worked by means of compound levers and weights, and it has to be very



[*The Bagley & Sewall Co., Watertown, N.Y.*

FIG. 179.—LICK-UP AND PRESS PART OF TISSUE MACHINE, WITH YANKEE DRYING CYLINDER AND CRÊPING DOCTORS

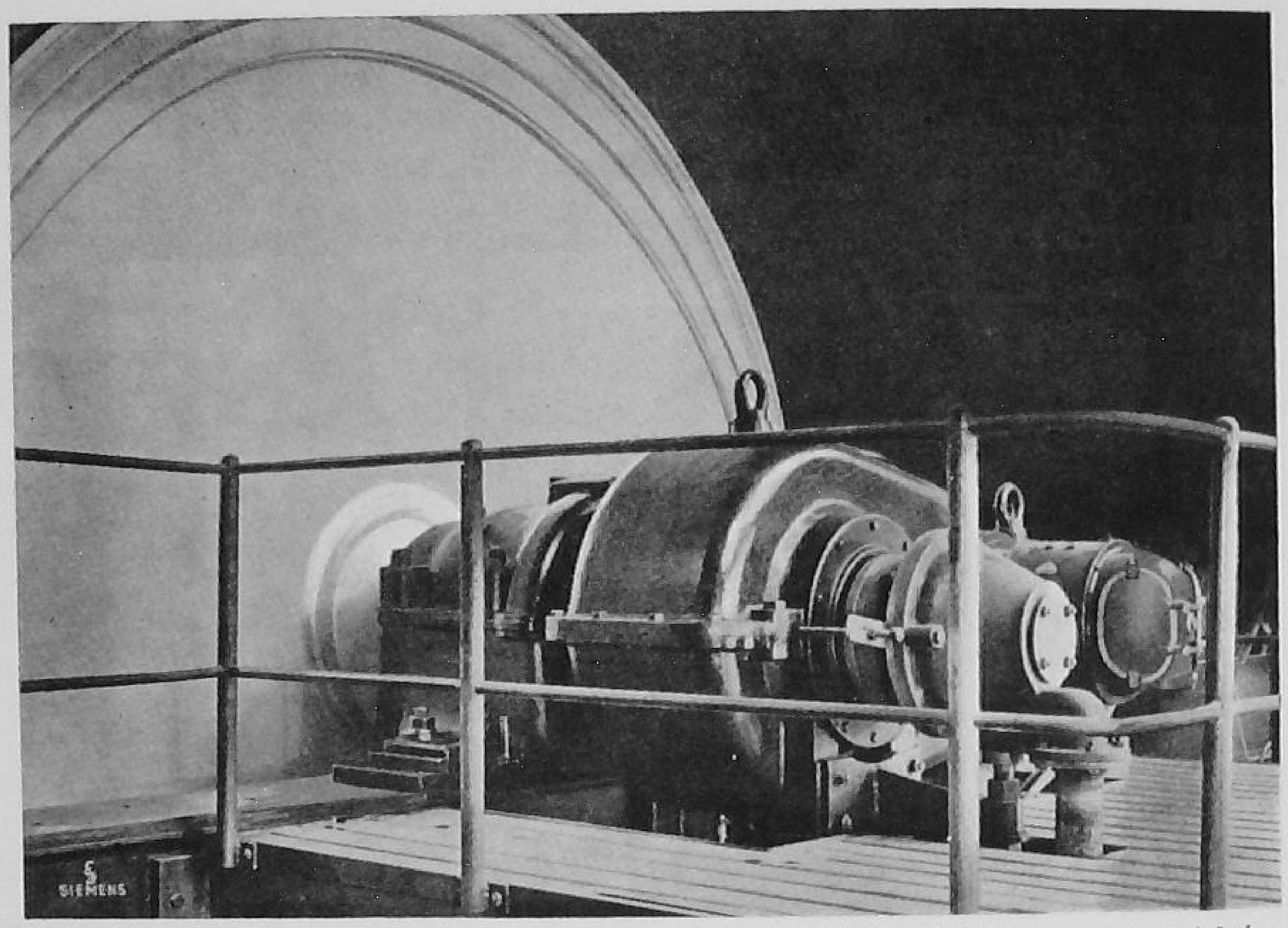
rigid to stand the strain and prevent it from springing in the middle and thereby reducing the pressure on the web.

Opinions differ as to the best position of this roll, but it is usually placed exactly under the centre of the cylinder, so that the nip given to the web of paper and felt is as direct as possible.

These press rolls were at one time made of iron, but they are now more generally covered with rubber, as they give almost equally good results and are much less hard on the felts.

On some machines the press roll is placed either in front or behind the centre of the cylinder, so that the pressure of the weighted lever does not

press directly to the centre of the cylinder, but to a point between the centre and the circumference, and has a dragging action. Our experience has led



[*Siemens-Schuckert (Great Britain) Ltd.*

Fig. 180.—Electric Drive fitted direct to Journal of a large M.G. Cylinder

us to favour the former method, and we are of opinion that the paper must stick instantly to the cylinder and remain fixed in close contact with it during the whole of the time it is passing round.

On other machines two cylinder press rolls are fitted, but we cannot understand the necessity for these, in spite of the fact that they are presumably giving good results, and they are being fitted to some of the latest machines. It would appear to be highly probable that the second press roll to come in contact with the web would interfere with the work done by the first one, in sticking the web to the cylinder.

We believe that two press rolls are the cause of a lot of trouble on M.G. machines. It is asserted that by having two rolls the pressure on each can be varied at will to suit the special requirements of the paper being made. We think this is very doubtful.

The overfelts are usually washed continuously after they leave the press roll, or if no washer is available they are sprayed with cold water to cool and clean them before they again come in contact with the web.

An important factor in determining the finish of both sides of the paper is the amount of water left in it at the wet press rolls. If a good finish is required, the web should be fairly moist on reaching the cylinder; and if a pronounced rib or stripe is required, or a rough underside, the wet press rolls should be let down very lightly or they may be hung up altogether. This will leave the web bulky and impressionable, so that the full effect of the overfelt can be produced.

The furnish of the paper and the way it is beaten have, of course, a very marked effect on the finish, as obviously very long and wild stuff will not take on such a good finish as finer stock, or a common brown as will a pure sulphite.

The state of fibrillation or wetness also has another important effect, in that if the stuff is *too wet* it may be impossible to get it to stick to the cylinder at all.

For kraft papers and sulphites it is usual to try to get the highest possible finish, while for lithos and certain other papers too high a gloss is not desirable.

It may be taken as a general rule that the purer the furnish used the easier will it be to keep the cylinder clean, and the making of common papers from refuse containing grit, oil, tar, etc., is very detrimental to the surface of the cylinder, as is also the use of bleached pulp from which the bleach residues have not been properly removed.

It has already been stated that about three-quarters of the cylinder is used for drying the paper; the other quarter is taken up by the cleaning and polishing apparatus, which must always be in as accessible a position as possible, in order to facilitate the changing of doctor blades, wire brushes, etc.

The principal piece of apparatus for keeping the cylinder clean is the ordinary doctor, preferably a Vickery, and there are usually two of these. One is fitted in position just before the cylinder comes in contact with the web at the press and the other one immediately after the paper has been pulled off the cylinder. This latter doctor removes the end of paper which comes over first, prior to its being wound on to the reel.

Between these two doctors may be fitted all kinds of cleaning devices to suit the individual tastes and fancies of the paper-maker. Another effective burnisher is a stiff wire brush, made by winding carding cloth round a wooden roll, and nailing it in position. The roll is driven at a high speed (250 revolutions per minute), the wire bristles cleaning and polishing the surface of the cylinder. A wooden doctor covered with a piece of damp felt is also used, and this is very effective in damping the fluff and dust which

dry on to the cylinder, thus enabling the steel doctor blade to remove them. The felt may be frequently changed if necessary.

A 'water' doctor is also very effective; it consists of a perforated pipe, which forces wet steam against the surface of the cylinder immediately in front of the iron doctor blade.

Apart from these devices for keeping the cylinder clean while it is in motion, it is also necessary periodically to grind it or buff it, or it may be cleaned with emery powder and oil. For grinding it, a perfectly true iron roll is fitted in position in place of the press roll, and driven at a higher speed than the cylinder by means of very tight belts in the presence of water.

This is a risky business, for unless the belts are kept *very tight all the time*, the motion of the cylinder will be bumpy and will result in flat places being formed, which will show on the surface of the paper later. The best way to carry out this work is to buff the cylinder with proper buffing apparatus. When the cylinder has to be stopped for any special cleaning, it should first be allowed to cool down, as the dirt is then more easily removed. If soft water is available for paper-making, it seems to be much easier to keep the cylinder clean than if the water is very hard.

The papers made on M.G. machines are very varied in character and uses, and the following are some of the most common: pressings, manillas for envelopes, litho papers for poster work, krafts, sulphite bag papers, common cap and cheap wrappings, tissues and sealings. The machine described is the commonest type, but there are many variations and modifications, of which the following are a selection:

1. An ordinary Fourdrinier wet end, followed by several small drying cylinders, which partly dry the paper before it is led to the large cylinder. The overfelt of this machine receives the paper from the last of the small cylinders, which are not usually very hot, and takes it to the cylinder press. The felt is damped just before the press nip. This arrangement enables higher speeds to be run, as the big cylinder is relieved of some of the drying, and it does not have any very detrimental effect upon the high surface which is obtained on the paper.

2. The 'lick-up' machine may have either a vat or Fourdrinier wet end, but it does not possess a wet press. Instead, the wet felt passes round the top couch roll, and the web is transferred to it at the couch, carrying it to the cylinder press and depositing it on the cylinder. The felt acts as wet felt and overfelt, and is usually passed through a washer to cool and clean it on its return journey from the cylinder to the couch roll. On this type of machine the *underside* of the web sticks to the cylinder and receives the polished surface.

If the wet end is of the vat type, as described in the following chapter, the web is made on the wire drum and transferred to the wet felt and thence to the cylinder.

3. A combination of both the above-mentioned types makes duplex paper in the following manner: the Fourdrinier wire part forms one side of the sheets and the other side is made on a cylinder mould situated above the wet end. The second web is led by a felt into the couch of the Fourdrinier wet end and the two webs are united, couched and pressed together at the same time, thus forming a duplex sheet or thin board. They are subsequently dried on the cylinder in the usual way.

4. Heavy boards may be made by having a battery of cylinder moulds exactly the same as those for the ordinary board machines, as described in the following pages.

It will be readily understood that the drying power of an M.G. machine is very limited compared to some Fourdrinier machines with their long double tiers of drying cylinders. For this reason it is usual to work the cylinder very hot indeed, as hot as the paper can stand without blistering.

Except in the case of very thin papers, high speeds cannot be attained, and for this reason better prices are usually obtained for M.G. papers than for similar qualities supercalendered or unglazed.

It is common practice nowadays to use an M.G. type of machine for making very thin tissues, such as facial and toilet tissues, at very high speeds up to 2,000 feet a minute or more. These tissues are about 8 grm. per square metre in substance; and even in the case of 21 grm. per square metre, crêped, at over 1,500 feet a minute. In this case the machine has a very short wire, and the stuff is very free and comes on to the wire very dilute from a high pressure closed inlet. On some of these machines the stuff is almost squirted on to the wire from the slice, at a slight angle, and most of the water passes straight through the wire into the pit.

Instead of the usual tube rolls there are doctors, or scrapers, under the wire which deflect the water into the pit, and only a few tube rolls to support the wire. There are only very few suction boxes, often only one, and the machine is invariably of the lick-up type, taking the very thin web of paper on to the felt at the couch probably by vacuum transfer, and passing it over the drying cylinder, at the other end of which it is usually taken off with a crêping doctor. There is a suction press at the M.G. drying cylinder to take the water out of the felt. This method of making thin tissues has reached a very high state of skill and perfection in the United States of America, where the speeds run are very great, and although the many mills making these

types of paper use slightly different methods, the principle is usually the same.

These very thin papers have quite an appreciable amount of crêpe in them as they come off the cylinder, but some of this is drawn out at the reel-up, and is finally somewhere in the region of 20 per cent to 25 per cent.

There is a very great demand for these types of toilet tissues in the United States, and it seems probable that the demand will also spread to Great Britain when pulp supplies become available, and also when the type of machinery required is installed in this country.

CHAPTER XX

THE BOARD OR VAT MACHINE

THIS important paper-making machine is very different from the Fourdrinier machine in the manner in which it makes or forms the web of paper,

[H. J. & A. Coulthurst Ltd.

FIG. 181.—A BATTERY OF CHESTS FOR SUPPLYING STUFF TO THE VATS OF A MULTIPLE-VAT BOARD MACHINE

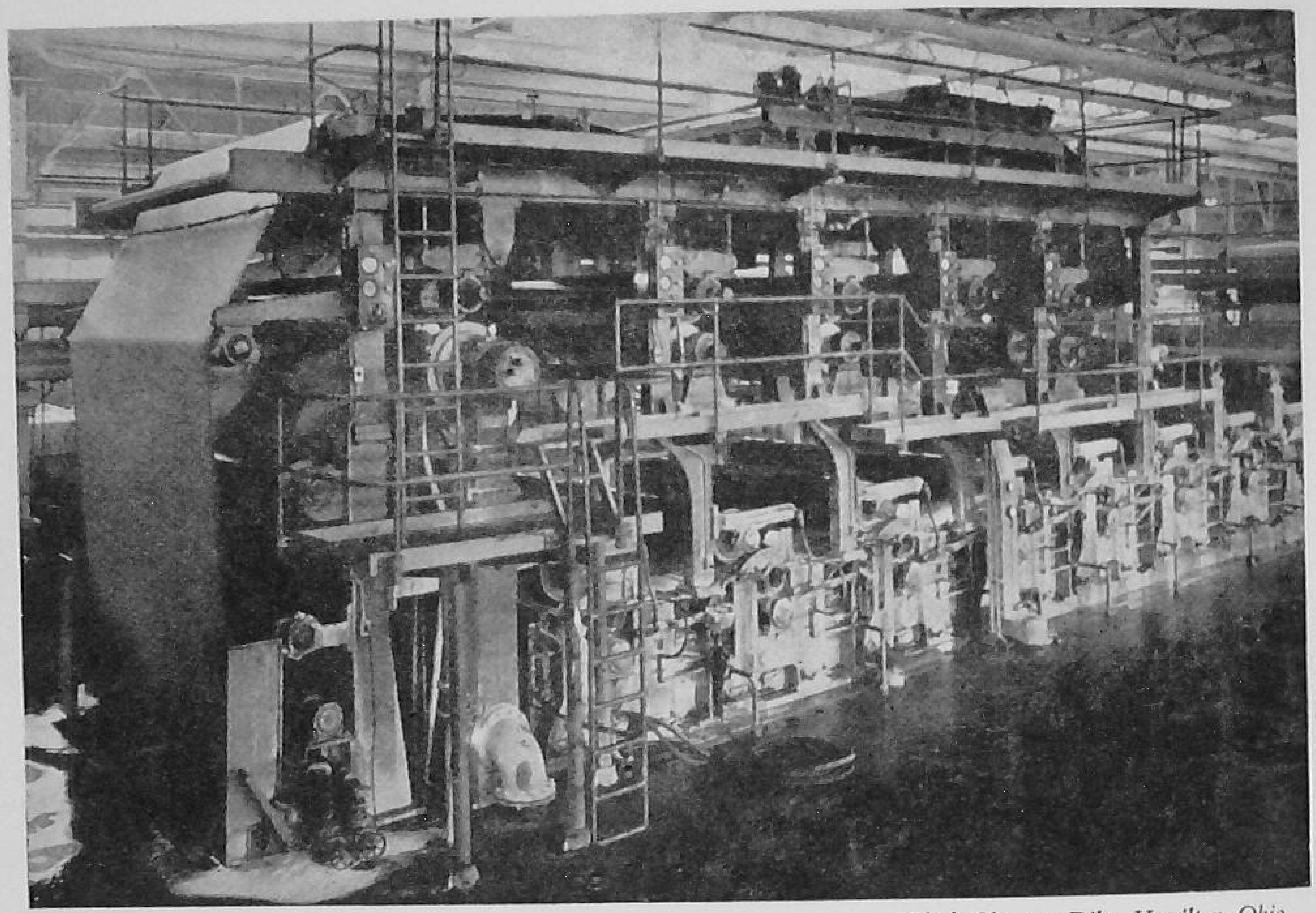
but it is the same as the Fourdrinier machine from the presses to the calenders.

The simplest type is the single-vat machine, which has no drying cylinders and is used for making very thick boards. It works as follows:

The pulp is pumped from the stuff chests to the stuff box and thence to the strainers; it then flows to a vat or trough, in which revolves a bronze cylinder, hollow in the centre and open at the ends, and with a covering of fine-mesh machine wire cloth over a stout backing wire.

The construction of the cylinder is much the same as that of a wove

dandy roll. As the cylinder revolves about two-thirds immersed in the stuff, the water in which the fibres are suspended rushes through the meshes of the



[*Black-Clawson-Dilts, Hamilton, Ohio*

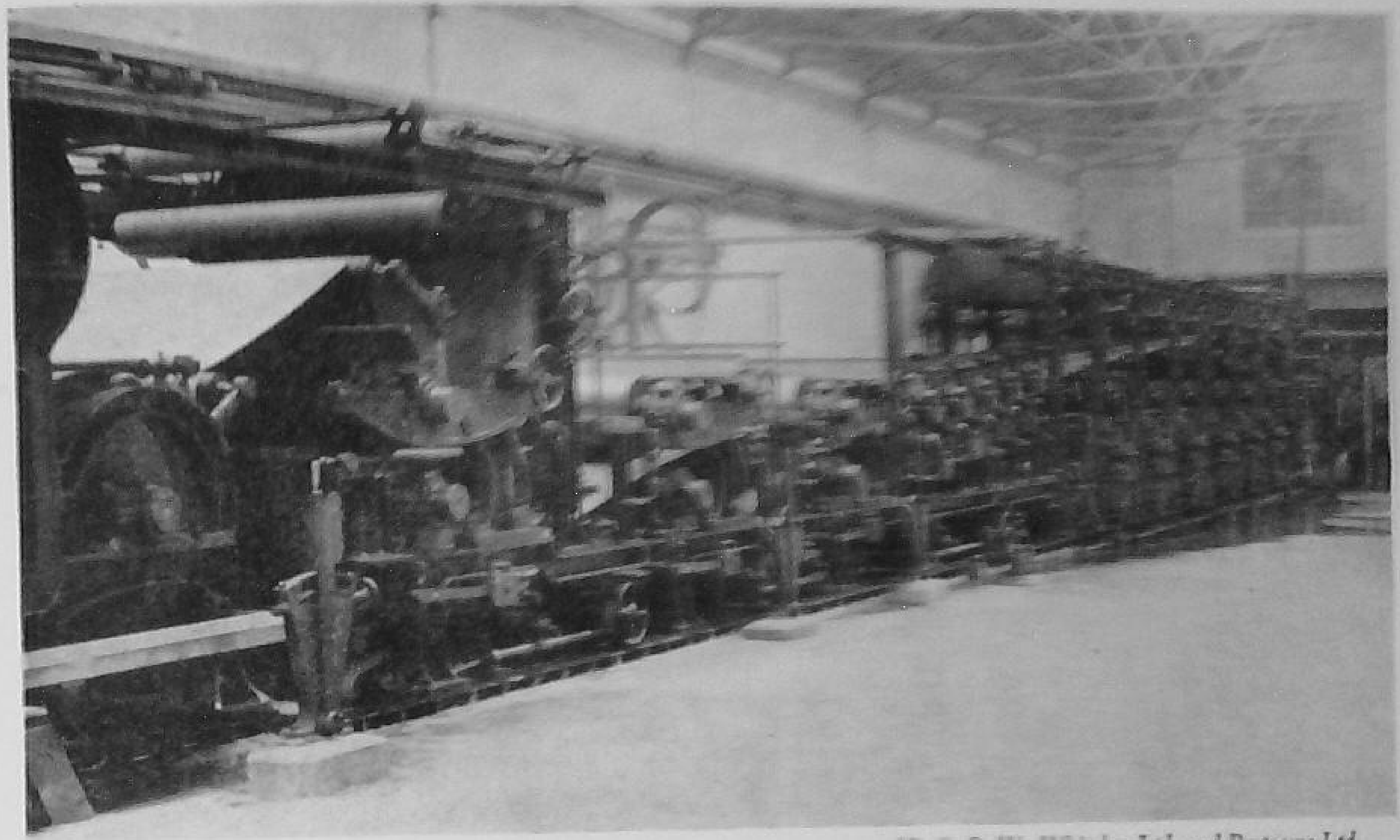
FIG. 182.—EIGHT-CYLINDER BOARD MACHINE WITH OVERHEAD PRIMARY PRESS SECTION

The sheet, after leaving the eighth cylinder, passes towards the 30 in. diameter suction roll and thence into the overhead primary press section, which consists of one suction drum, three plain presses and one suction press. The loading of all top rolls is provided with pneumatic control.

wire in the same way as it runs through the wire on the wet end of a Fourdrinier machine. As, however, the meshes are too fine to allow the passage of the fibres, the latter cling to the surface of the wire drum, and thus a film of fibres is formed on the revolving mould.

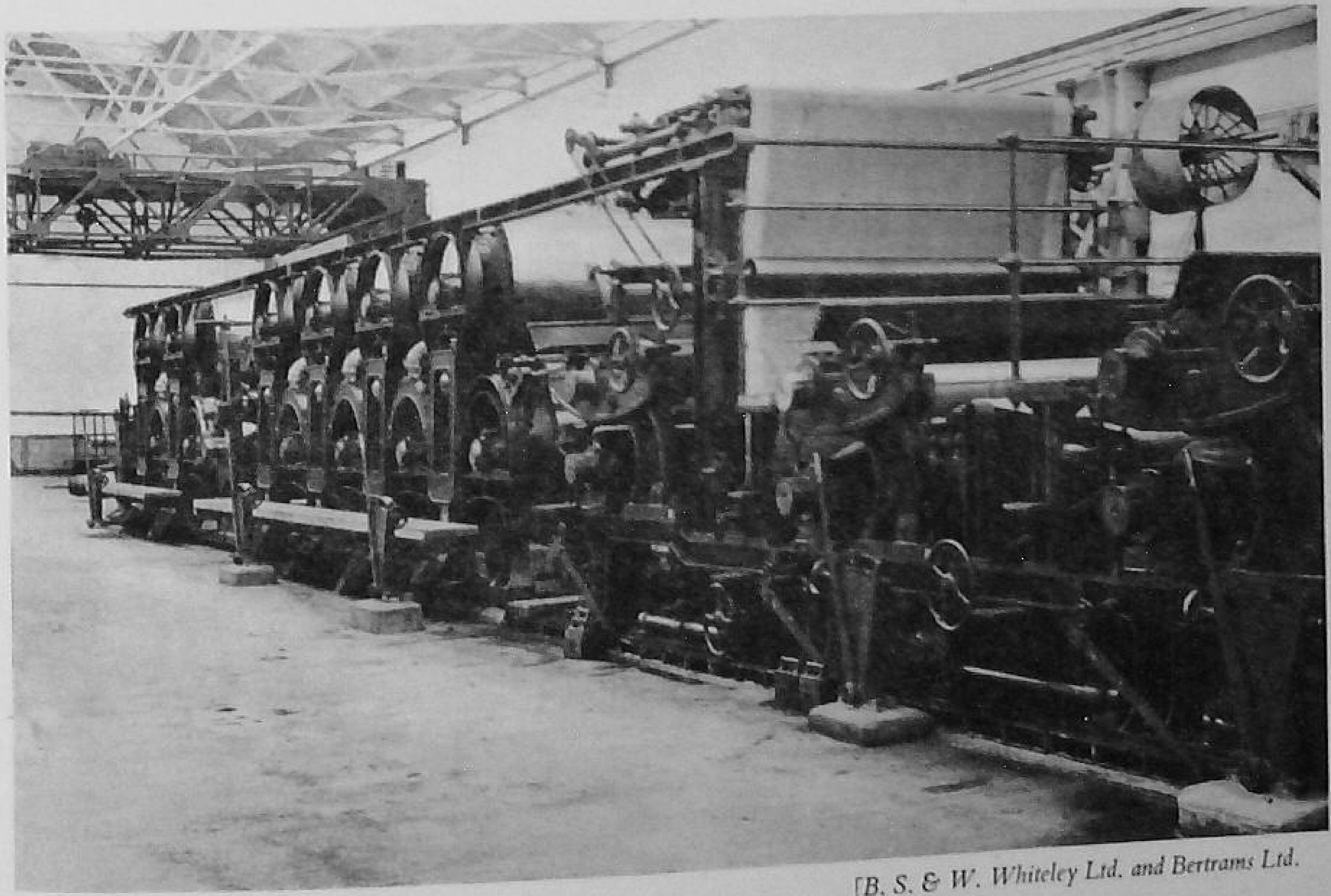
As the drum moves round towards the top, the film of stuff is lifted clear of the stuff and water in the vat, and more water drains away. When the wet film reaches the highest part of the circumference of the roll it comes in contact with an endless travelling wet felt. As the web touches the wet felt it is couched by means of a felt-covered roll, which presses the travelling felt against the surface of the drum. In this way the wet film of pulp is picked up from the wire surface and adheres to the felt.

The felt carries it along to squeezing or press rolls, where it is relieved of as much water as possible. The web sticks to and is wound round and



[B. S. & W. Whiteley Ltd. and Bertrams Ltd.

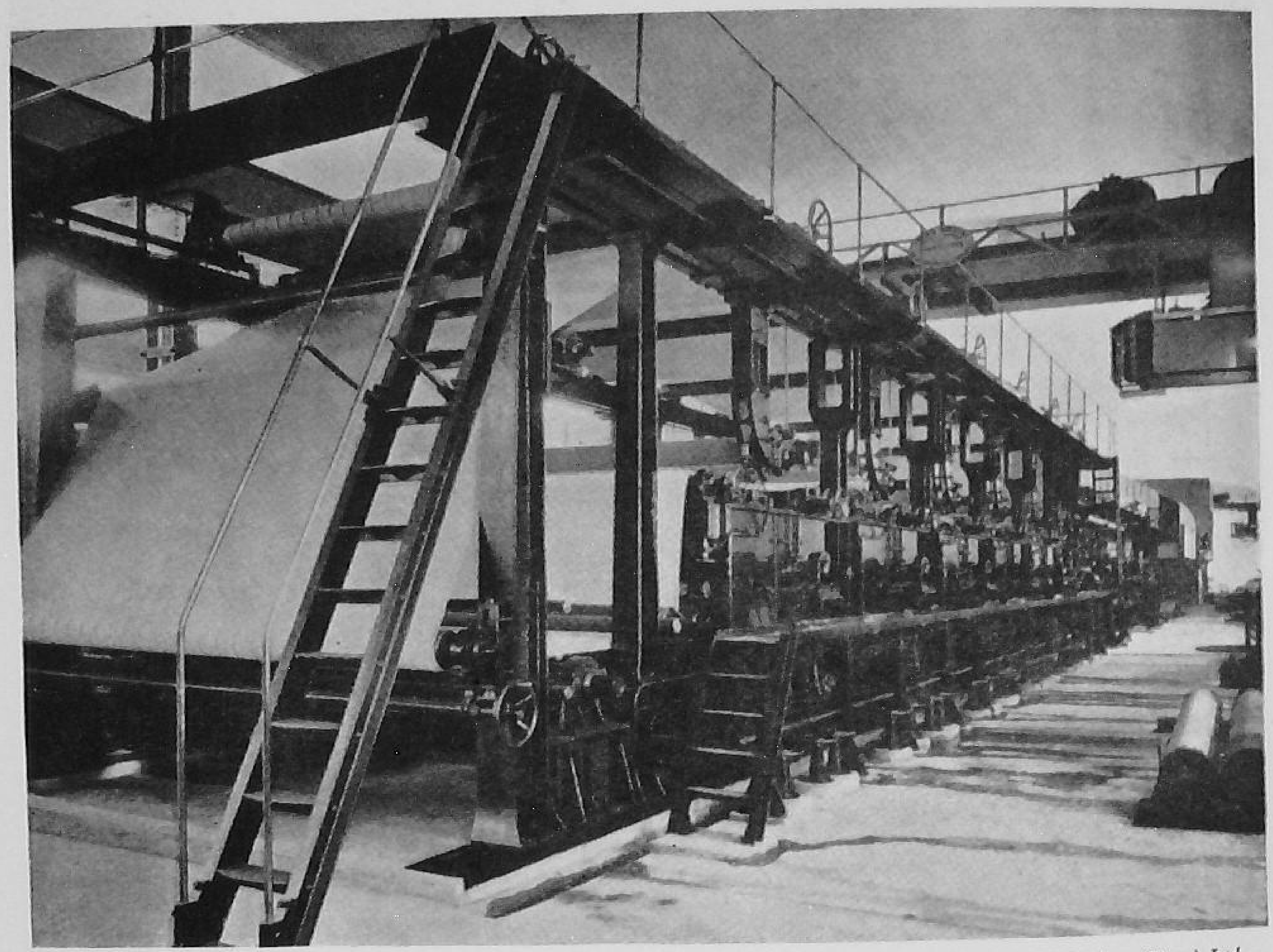
Fig. 183.—Eight-Vat Board Machine, showing Vats, Baby Presses, Main Presses, and the First Drying Cylinders



[B. S. & W. Whiteley Ltd. and Bertrams Ltd.

Fig. 184.—Presses and Dryers of Board Machine

round the top press roll until a sufficient thickness has been formed. This is indicated automatically by the ringing of a bell. It is then cut off by hand, laid in a pile, pressed and finally dried by hot air.



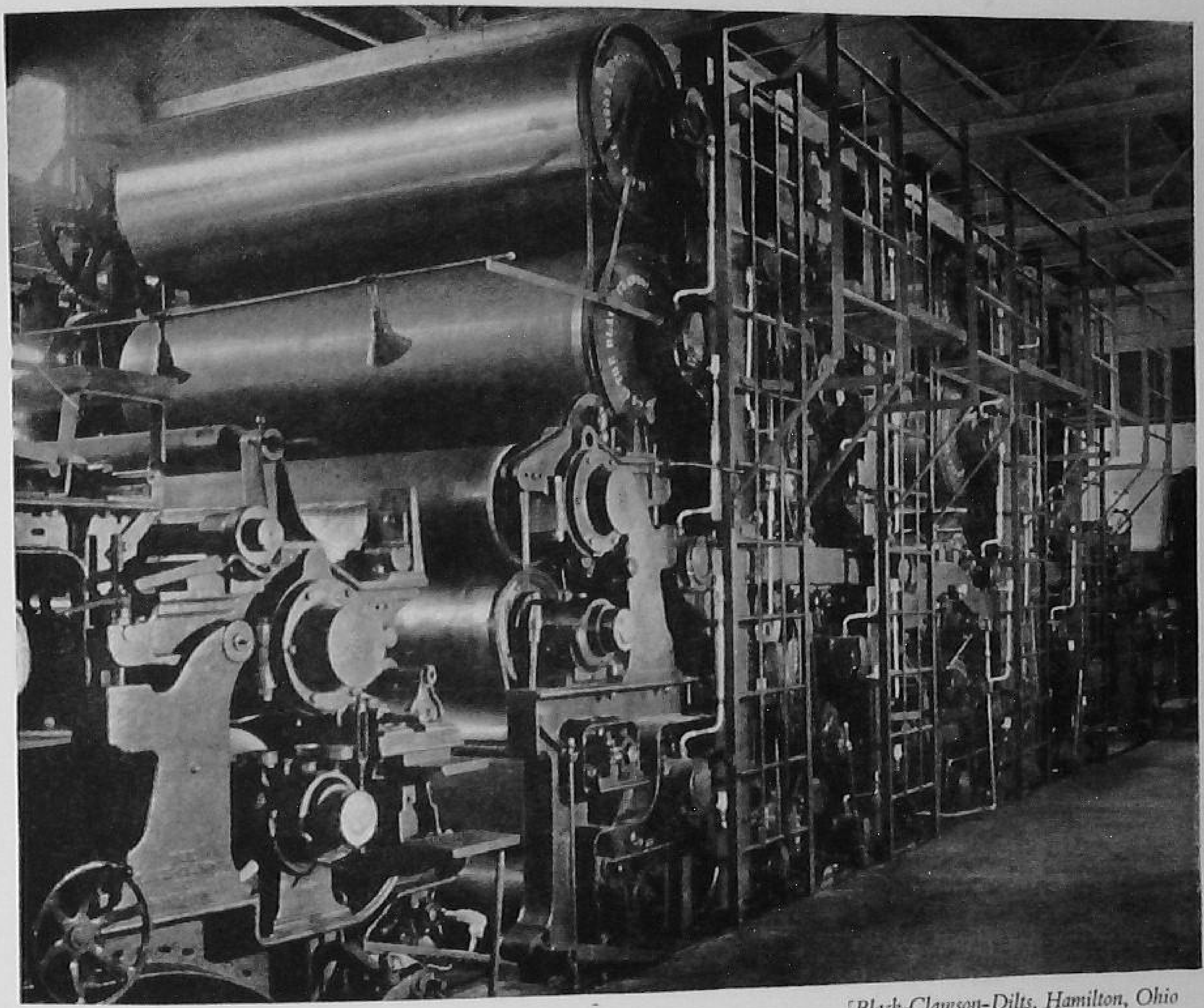
[*St. Anne's Board Mill Co. Ltd. and Walmsleys (Bury) Ltd.*

FIG. 185.—DRYERS OF BOARD MACHINE

The resulting paper is known as a board, and such boards are used for boxes, panels, suitcases, etc. Larger machines are provided with drying cylinders and calenders for drying and glazing the board as it is made. By using two stuff chests, two sets of strainers and two vats, a board can be made of two different qualities of colours—that is to say, it may consist of common brown paper stuff on one side, and have a white top side made of sulphite pulp, or of stock of any colour. Such papers are known as duplex, which means that they are two-sided or two-ply. The width of the web which is to be made on the drum is regulated by stopping up the meshes of the wire by tapes, which may be wound on at either side. This obviously has the effect of closing the meshes of the wire cloth, so that water cannot run freely through and cause the formation of a web of fibres.

The water which passes through is run away to a back-water box, whence

it is pumped back again for further use in furnishing the beaters. The thickness of the web which will form on the cylinder is obviously limited, for, as it



[*Black-Clawson-Dilts, Hamilton, Ohio*

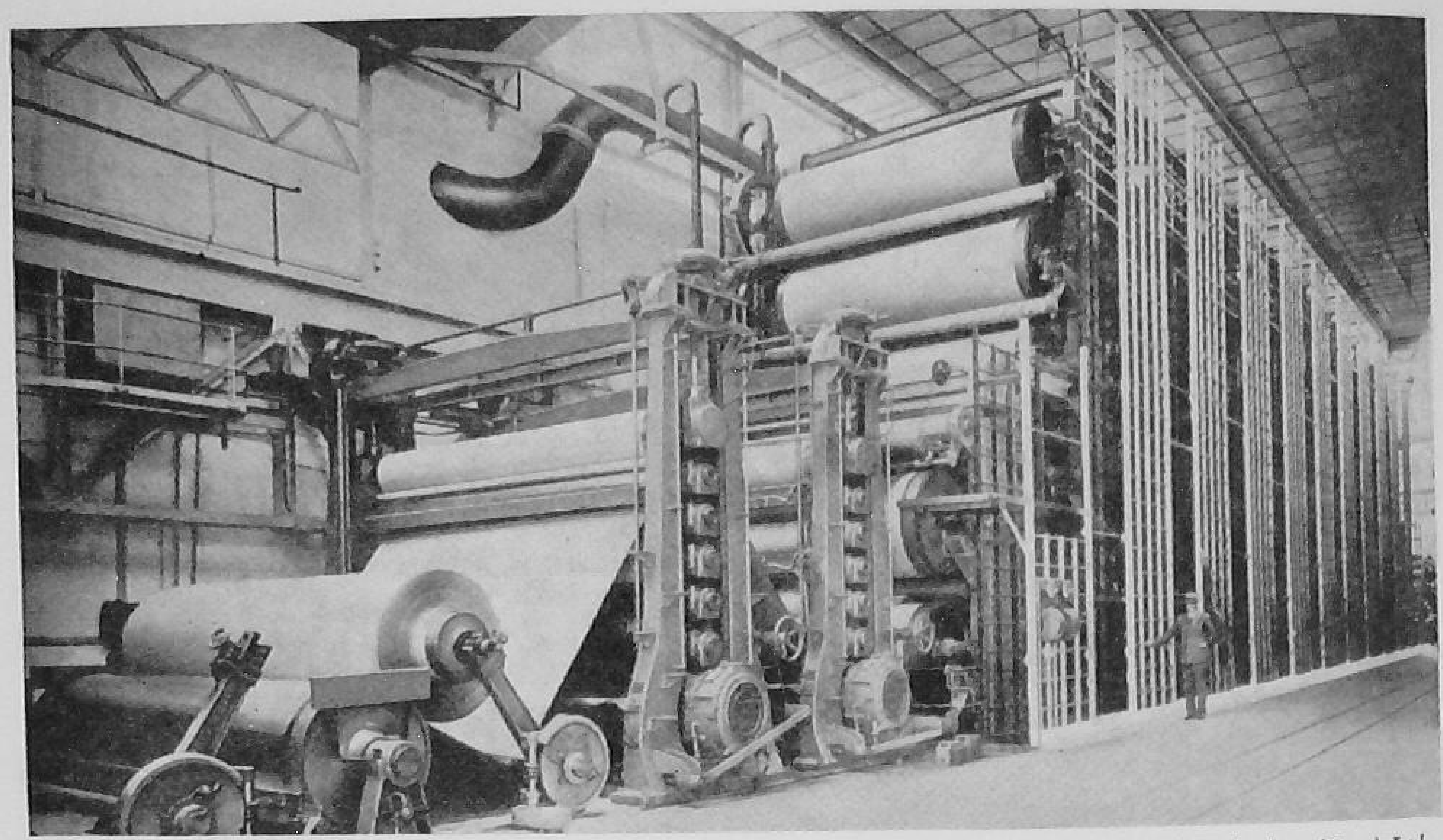
FIG. 186.—STACKED DRYERS OF BOARD MACHINE

becomes thicker, less and less water can pass through, and so the number of fibres deposited becomes less. The thickness of the various webs which form the board is regulated by the consistency of stuff going to the vat, and by the speed of the machine.

In order, however, to produce a thick board suitable for making folding boxes, or a paper which has to be very thick and stiff, the number of vats and making drums may be increased to four or even six or eight, and all the webs pressed together to form one thick sheet (Figs. 182 and 183).

In this way boards may be made with a different-coloured surface on each side and with a 'middle' of an entirely different colour and quality. To do this it will be seen that different sets of beaters will be required, also a number of stuff chests, mixing boxes and strainers, to correspond with the number of qualities of stuff to be used to compose the finished board.

Each chest requires a separate stuff pump, and where stocks of different colours are being used, separate back-water pumps and tanks are needed to



[*Thames Board Mills Ltd. and Walmsleys (Bury) Ltd.*

FIG. 187.—STACKED DRYERS, CALENDERS, AND REEL-UP OF LARGE BOARD MACHINE

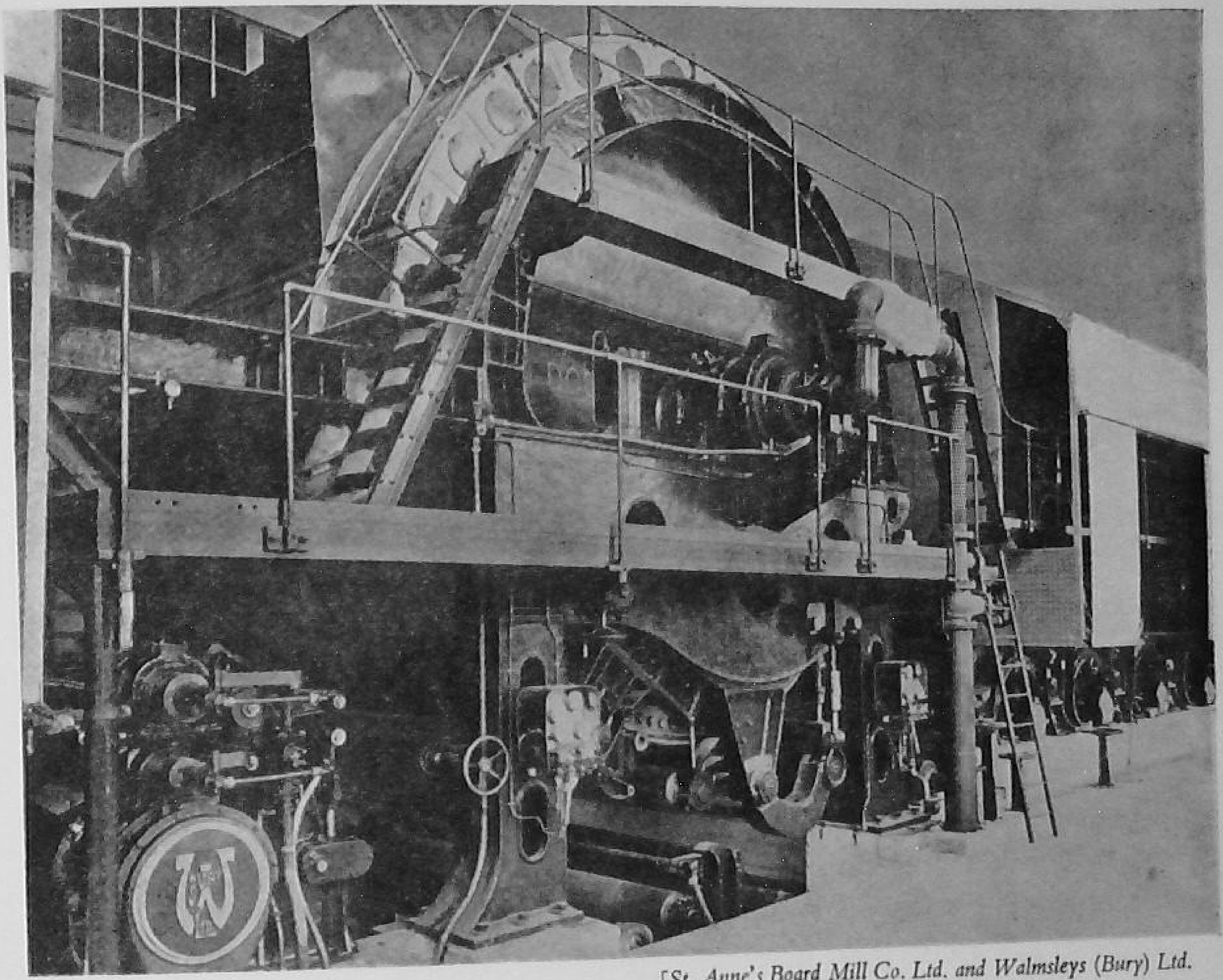
pump back and store the water from the vats for the beaters or mixing boxes. From the foregoing it will be gathered that the wet end of a multi-vat machine is a somewhat complicated and costly affair.

To take the case of a four-vat machine: the vats are arranged close together, and in rotation, the first one to deliver its web of stuff to the wet felt being the one nearest the presses, and so on in a reverse direction towards the strainers. When the fourth web has been picked up, the felt will be fairly heavily loaded, and here it turns round a roll and travels back towards the presses of the machine carrying the four-ply web on top and immediately above the vats.

The presses at first are small and fairly light, and are placed in rotation, in steps, leading down to the main heavy press roll. These small presses are generally called 'baby' presses (Figs. 182 and 183), and they serve to squeeze and incorporate the four webs of paper together gradually before the main pressure is applied by the heavy press, which is usually of granite.

The 'baby' presses are of wood or metal, and are usually from five to seven in number; the web passes straight through them and is not reversed.

At the 'baby' presses another felt comes into action and is in contact with the upper side of the paper during its passage through them.



[St. Anne's Board Mill Co. Ltd. and Walmsleys (Bury) Ltd.

FIG. 188.—M.G. CYLINDER FITTED AT THE END OF THE DRYERS OF A BOARD MACHINE

The wet felt carries the web right to the main press roll; this wet felt passes through a felt washing-tank and squeezing rolls before returning to the vats to pick up a further web of paper.

The majority of papers made on board machines are either 'duplex' or 'triplex', the former having, as a rule, a face of pure sulphite and a back of a mixture of mechanical pulp and waste papers, the proportions being 25 per cent face and 75 per cent backing.

In the drying of boards it is not the general practice to use dry felts, and on some of the big modern machines, in order to save space, the drying cylinders have been arranged in tiers, five or six high. We believe that this practice originated in America, but we are not at all certain that it is an unqualified success.

It is almost universal practice to combine a system of hot air with the

drying cylinders, in order to absorb the large amount of moisture given off into the pockets between the tiers of cylinders, and between the cylinders themselves.

On many board machines the paper is calendered on machine calenders, and then cut at the end of the machine, instead of being reeled and cut separately.

This is not, as a rule, a difficult matter, as board machines run at a comparatively slow speed when compared with some modern paper-making machines, although, of course, the output in weight may be very high.

In the case of triplex boards the usual furnish is face and backing of the same material, such as sulphite, with a middle of poorer quality, such as strawboards and mixed waste papers.

This arrangement necessitates the use of only two sets of beaters and chests, a great saving of space and power. The usual 'finish' is a water-finish put on with chilled iron rolls in two tiers on to which water is led from a trough. Soap is usually added to the trough to prevent rusting. The paper passes from the second stack moist, and the finish is put on during its passage through the two remaining stacks. Four stacks of calenders have therefore to be provided.

The 'Mould' Machine

The so-called 'mould' machine is used for making imitation hand-made papers, and papers made on these machines are the nearest approach to hand-made paper which has yet been achieved by mechanical means.

The paper is, however, inferior to genuine hand-made paper.

It is possible on this machine to make paper with a deckle edge all round the sheet, and this fact alone is liable to mislead those who are not experts into mistaking the 'mould' made for the real hand-made sheet.

Great secrecy is observed in some mills possessing these mould machines; the wet end, consisting of strainer, vat, wire-covered cylinder and presses, is sometimes placed in a locked room, and the wet web is led on a felt through a slit in the wall into the drying room.

The 'mould' or cylinder is just like a large-diameter dandy roll, and it revolves partly submerged in the stuff in the vat.

This roll has the devices and lettering, etc., fixed to its woven-wire cover, and as it revolves it picks up a layer of stuff, thick where the cover is plain cloth, and thin where the device wires are placed.

The wet film of stuff is couched off at the top and taken on a felt to the presses in exactly the same way as the stuff is couched off the drum of a board machine.

[Bertrams Ltd

FIG. 189.—MILL FOR MAKING BOARDS

Included in the drawing are Milne's patent beaters and an 8-vat board machine, with baby presses and patent hot-air cylinder framing.

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[Bertrams Ltd.

Fig. 75.—Latest Type Fourdrinier Machine

This machine is erected on the first floor with basement underneath for pumps, felt cleaning, hog-pit and other auxiliaries.

[To face page 206

If the paper is to be made in single sheets, strips of wire are placed round and across the roll to fix the dimensions of the sheet. No stuff, or very little stuff, adheres to this wire, so that when the wet sheets have been pressed they come apart, or are easily pulled apart by hand, leaving a 'deckle' edge.

The machines are so arranged, and fitted with four or five or more drying cylinders, that the paper may either be dried at once by steam, or may be removed from the felt by hand as wet waterleaf and dried by air in a loft.

The Richardson-Key expanding cylinder 'mould' is sometimes used on these machines, owing to the ease with which a new wire cloth cover may be fitted when changing from one water-mark or size to another. This patent 'mould' enables a great saving to be made in the stock of 'moulds' or drums, which would otherwise have to be carried.

Two and Multiple Wire Machines

In recent years increasing use is being made of Fourdrinier machines with more than one wire. The object of this is twofold. In the first place it enables a paper to be produced with two top sides on which to print. This is achieved by running together the under or wire sides of two thin papers, leaving the two top sides outermost. It is thus possible to produce a printing paper with exactly the same surface on each side of the sheet. The method is also applied to make paper of very great strength, and two or more wires may be used for this, giving a two- or three-ply sheet. Some mills have been doing this for a long time, but the practice has not been general. More frequently a Fourdrinier wire has been used in conjunction with a vat such as that used on a mould machine, but now that the difficulties of combining the two sheets at the press have been overcome, the use of two complete Fourdrinier wire parts to form the sheets is quite common practice. The sheets are brought together at the press, where they become homogeneous and pass on through the second and third press and across the dryer as one solid sheet.

It is not, of course, possible in this case to make satisfactory laid or water-marked sheets.

MODEL CENTRE FOR VILLAGE INDUSTRIES, 25 SEP 1957 T. KALLUPATTI. MADURAI DT.

CHAPTER XXI

THE MANUFACTURE OF NEWSPRINT

PRODUCTION FIGURES—FIBROUS RAW MATERIALS—NON-FIBROUS RAW MATERIALS—HANDLING OF RAW MATERIALS—WATER—PREPARATION OF ALUM, LOADING AND DYES FOR ADDITION TO STOCK—PREPARATION AND PROPERTIES OF STOCK—STRAINERS AND SLICE—THE WIRE PART—THE PRESS PART—THE DRYER PART—FINISHING—FUTURE TRENDS OF NEWSPRINT MANUFACTURE

IN the descriptions of paper-making practice given in other chapters (notably in Chapters XV, XVI and XVII) there is a good deal of information which is applicable to the manufacture of newsprint. Nevertheless, since newsprint-making has tended to become increasingly specialized—if only because of the ever-growing necessity for reducing conversion costs by the development of larger output machines running at high speeds—it will be useful in this chapter, not only to give a brief general discussion of the technique of this branch of paper-making, but also to draw attention to various aspects of it which are peculiar to newsprint. The subject is treated primarily from the viewpoint of the manufacturer in this country who does not prepare his own pulp, but purchases it ready-made. Some details of the processes for pulping wood for making newsprint are, however, given in Chapter V (see pp. 65, 73, 79, and 80).

Production Figures.—World production of newsprint in 1938, the last complete year uninterrupted by war, was 6,710,000 long tons. The greatest quantity yet manufactured in a single year was 8,020,000 tons, which was the world output for 1937. The world production of paper of all kinds for 1937 was 20,500,000 tons; thus newsprint accounts for about 40 per cent of this total.

These figures give some idea of the importance and size of the world's newsprint industry.

Even more striking, perhaps, is the rate at which the annual production of newsprint has increased. In Canada, for instance, to take an outstanding example, the production in 1913, the year immediately preceding the war, was 310,000 tons. In the peak year of 1937 the production rose to 3,250,000 tons—a tenfold increase. Enormous expansions of this kind have been made possible not only by building new mills, but also by increasing the size, the speed and the efficiency of the machines used to make this class

[James Bertram & Sons, Ltd.

Fig. 190.—The Two Wire Parts and Press Part of a Twin-Wire Machine, showing the Method of bringing the Under Sides of the Two Sheets together at the Main Press

[To face page 372

of paper. Newsprint manufacture has, in fact, been largely responsible for leading the industry, with ever wider and faster machines. This, of course, is a logical development, since newsprint must always remain one of the cheapest grades of paper made, and it is also required in quantities that far exceed any other class of paper.

The majority of modern Fourdrinier newsprint machines in operation to-day are designed for maximum paper widths ranging from about 200 to 250 inches, but a notable exception is the world's largest machine, which makes paper 304 inches wide. This is an all-British machine operating in England.

The most common speeds of modern newsprint machines range from about 1,050 to 1,250 feet per minute, while the highest authentic speed is in the neighbourhood of 1,400 feet per minute. Machines of this kind naturally produce a lot of paper. The output of the 304-inch machine, for example, when making super-calendered paper of normal substance (55 grm. per square metre), reeled and ready for the customer, exceeds 200 tons per 24 hours.

The fibrous raw materials for newsprint are prepared exclusively from wood, and it takes, very roughly, a cord of wood to produce a ton of finished newsprint; a cord being a pile of logs, all lying parallel to each other, 4 feet high, 4 feet wide and 8 feet long. A cord of wood corresponds, very approximately, to eight trees having an average height of usable trunk of about 50 feet, and an average diameter of about 18 inches. Calculating from the basis that a typical pre-war daily newspaper of about 16 pages weighed 4 oz., the amount of pulp required for a circulation of two million copies was over 200 tons (air-dry) per day. This means that rather more than 800 trees had to be cut down every day to satisfy the requirements of only one of the leading newspapers published in this country.

Altogether, the average daily consumption of newsprint in the British Isles during 1938 was 3,400 tons, the consumption for the year having reached the total of 1,241,000 tons. The corresponding annual consumption per head of the population was about 60 lb. It is interesting to compare these figures with those for North America (Canada, U.S.A. and Newfoundland). The total consumption for the same year, 1938, was 3,088,000 tons, which gives a daily consumption of 8,500 tons. Although these figures are two-and-a-half times greater than the figures for this country, the consumption per head in North America was somewhat lower, being about 53 lb. per year. During 1938 the British Isles and North America together accounted for 62 per cent of the world production of 6,710,000 tons.

These enormous tonnages give some idea of the inroads being made into

the forests of the world to satisfy the demand for newsprint. The question of the continuity of wood supplies has, as a result, given rise to some anxiety, and from time to time it has been concluded that the world is in sight of a serious shortage. Although these scares appear to have been unjustified, they have at least drawn attention to the need for organized schemes of wood-cutting and afforestation to ensure that, with steadily increasing demands, the wood supply is maintained. Nearly all the major wood-pulp producing countries, and especially the European ones—Norway, Sweden and Finland—have their forests continuously surveyed, in order to check consumption against the annual rate of growth. As a result, the necessary afforestation measures are enforced.

Fibrous Raw Materials.—By far the most common variety of wood used for newsprint manufacture in Europe is spruce (see p. 62). This wood is converted both into groundwood (mechanical pulp), and also into sulphite pulp. Very exceptionally sulphate pulp is used. Groundwood is the most inexpensive fibrous material (other than waste paper) available for newsprint, but apart from this advantage it is particularly well-suited for newsprint production. It has the necessary absorbent properties to take the printing-ink well, and it has good opacity. In fact, it has often been said, quite rightly, that to obtain the best printing results it would be preferable to use groundwood alone. In practice, however, a proportion of pulp, longer fibred than groundwood, is necessary, mainly to help the immature sheet to have the requisite strength to be carried on its journey along the paper-machine, from the couch, through the presses to the drying cylinders. The pulp most commonly used for this purpose is known as news quality, or strong, sulphite pulp. Occasionally sulphate pulp is preferred to sulphite pulp, but its selection is justified only on those rare occasions when it is cheaper than sulphite pulp, due to exceptional market conditions, or because a newsprint mill is in close proximity to a sulphate mill where supplies of pulp may be available in slush form at a competitive price. Actually sulphate pulp has the advantages of a somewhat longer fibre than sulphite pulp, and it is free from resinous substances. On the other hand, even in the palest grades, it is usually rather darker in colour than strong sulphite pulp, which is an objectionable feature if bright, nearly white shades are required, as is mostly the case nowadays in this country.

At the present time the proportion of chemical pulp used with groundwood for a newsprint furnish ranges from about 10 per cent to 20 per cent. Some years ago the amount commonly used was as high as 30 per cent, but, partly due to the need for retrieving some profit out of the ever-decreasing selling price of newsprint, and partly due to a growing understanding of the

importance of groundwood for giving good printing qualities, the sulphite percentage has been steadily reduced. Improvements in groundwood manufacture, resulting from scientific research, and also the development of reliable methods of pulp evaluation, have helped to make the reduction in sulphite content practicable.

Non-Fibrous Raw Materials.—Mention must be made of the two other raw materials that occur in appreciable proportions in newsprint. They are loading and water.

Loading is added to newsprint to increase ink receptivity, to help to give satisfactory opacity and to fill up inter-fibre spaces so that a smoother surface may be obtained; it also helps to make a sheet of paper as economically as possible. China clay is the most common loading for newsprint, although in some American mills calcium carbonate is used, because china clay is expensive; the reason being that it occurs only to a limited extent in the United States, and a good deal has, therefore, to be imported from Cornwall. In one American mill, calcium carbonate is made from carbon-dioxide recovered from the flue gases of the boiler plant. In other mills, loading is not used at all, because of the expense of transporting it to the mill site.

The cheaper grades of clay, even down to mica clays, are quite satisfactory for newsprint, provided the abrasive grit content is not too high. This is an important point to watch, otherwise excessive wire wear may result. The colour of the clay, unless it is exceptionally bad, has no appreciable effect on the shade of the finished newsprint paper, and it is, therefore, only a secondary consideration. The amount of loading carried may range from 2 or 3 per cent up to 12 per cent or more, depending on the properties desired, the basis weight of the paper and other factors.

The last of the four major constituents of newsprint, water, is the cheapest, but it is by no means unimportant, neither is it put in primarily for reasons of economy. Newsprint devoid of water would, like any other paper, be of very inferior quality. The presence of the correct amount of water, which should be between about 8 per cent and 10 per cent, is helpful in obtaining a satisfactory finish; it gives paper a mellow handle (if it is too dry it will be harsh and brittle; if too wet it will be soft and flabby); it minimizes the possibility of troubles due to static electricity during printing, and it reduces the tendency to cockle during transport and storage.

The analysis below gives the proportions in which the four constituents mentioned occur in a typical sample of newsprint.

Groundwood	70%	or 84%	expressed as a percentage of the fibrous furnish only
Sulphite pulp	13%	or 16%	
China clay	8%		
Moisture	9%		

Handling of Raw Materials.—Raw materials for newsprint are required in large quantities, and therefore up-to-date methods of handling and transporting are an essential part of a modern mill. It is of prime importance that the site should have good rail and water transport facilities; and, in addition, road transport is essential, as it is used almost exclusively for the distribution of paper to customers in this country. It is also used for conveying general stores, machinery and the less bulky raw materials, such as dyestuffs, to the mill.

A well-located newsprint mill, producing, for example, 3,000 tons of paper per $5\frac{1}{2}$-day week from four modern machines, will consume approximately 4,500 tons of moist mechanical pulp, 500 tons of air-dry sulphite pulp, 300 tons of china clay, and 2,000 tons of coal per week, all of which will be delivered by ships carrying anything from 1,000 to 5,000 tons or more of cargo. These ships come alongside the mill wharf for unloading. Coal and china clay are grabbed out by the wharf cranes and discharged direct into the bunkers provided. Pulp is lifted from the ship's hold, usually four or five bales at a time, on to trucks belonging to the mill, and the bales are tidily stacked subsequently, using gantry cranes.

Coal is conveyed into the mill continuously by bucket or belt conveyors, and clay is usually slurried in a building integral with the clay bunker, the slurry being then available for pumping to the point at which it is mixed with the stock in the mill. Pulp is reclaimed from the stacks by the mill gantry cranes and taken to the beater floor, either by electric trucks or in some cases direct by crane.

The handling of newsprint raw materials has been specially mentioned in order to emphasize the important point that with only a relatively small margin between raw material costs and the selling price of the finished product, conversion costs, which of course include the cost of handling materials, must be kept to the most economical level possible. Newsprint to-day is essentially a cheap product, mass-produced in enormous tonnages. Every effort must, therefore, be made to ensure that labour is not wasted by inefficient methods of handling materials.

Water.—The water supply for processing the paper is obtained usually from wells, although in some cases it is drawn from rivers. River water often requires rather elaborate flocculation and filtration treatment, but well water has the advantage that it rarely needs any treatment at all. The quantity required for all paper-making purposes will be of the order of 12,000 gallons per hour per machine, which, at 6 tons per hour production per machine, is 2,000 gallons of water per ton of paper manufactured. Of this quantity the dryers will evaporate about 2,500 gallons per hour, the remainder being

[Stothert & Pitt Ltd.

FIG. 191.—$2\frac{1}{2}$-TON CRANES USED FOR UNLOADING PULP, COAL, AND CHINA CLAY DIRECT FROM OCEAN-GOING SHIPS

necessary to make up incidental non-recoverable losses, such as hosing floors, machine wash-ups and water drained away from the presses. For safety a supply should be available considerably in excess of this rather economical quantity of 2,000 gallons per ton. It should, however, be the aim to keep the water consumption on the machines to as low a figure as possible, not so much because water may be difficult to obtain, as because extravagance will almost invariably be linked with excessive fibre losses. Modern newsprint manufacture calls essentially for a closed back-water system, which means that as large a quantity as possible of the water should be used over and over again. Any water added in excess of that subsequently removed by the machine (principally at the dryers) will be wasted water, and unless an efficient fibre recovery system is available, the loss involved is likely to be serious. With an adequately balanced water system, a recovery unit is not, as a matter of fact, essential.

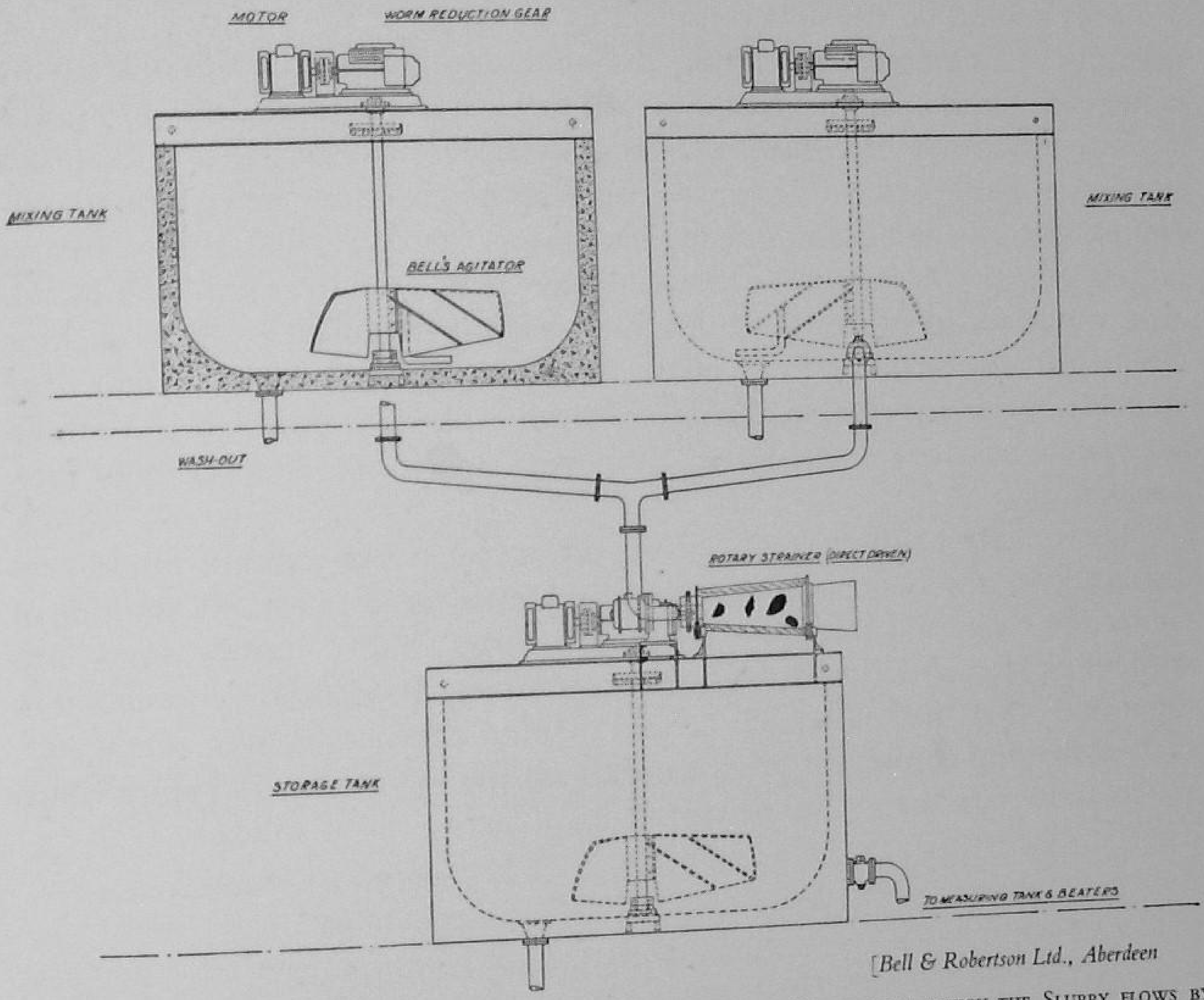
The quality of the water used for the actual paper-making process, as distinct from the boiler plant, is not of material importance. It should, of course, be clear, and free from suspended matter, but it may be very hard without giving any serious paper-making troubles. Indeed, it is contended in some mills that hard water has certain definite advantages over soft water, such as helping to prevent pitch troubles on the machines. A typical hard water, quite satisfactory for newsprint manufacture, is as follows:

Ca	9·7 parts per 100,000
Mg	3·2 " " "
Cl	9·6 " " "
SO_4	2·1 " " "
Hardness, permanent	10·0 " " "
" temporary	27·2 " " "

Preparation of Alum, Loading and Dyes for Addition to Stock.—The most efficient practice in newsprint mills to-day demands that all the auxiliary materials, loading, alum and in many cases dyestuffs, should be added to the stock in suspension or in solution.

China clay, as already mentioned, is mixed into a slurry with water, in the clay-mixing house, which should be adjoining the clay store. The clay is mixed in tanks, fitted with the necessary agitator gear, to give a concentration of about 2 lb. per gallon. From the mixing tank the slurry is pumped through a screen, usually made of old machine wire, to a storage tank. The slurry must, of course, be continually agitated to prevent sedimentation. In some installations it is found convenient to have two or three mixing tanks, each feeding one large storage tank. From the storage tank, the slurry is pumped to a small service tank in the mill, which supplies the machines by gravity. To prevent sedimentation, slurry from the service tank overflows

continuously, the surplus being collected in a receiving tank, from which it is pumped back to the storage tank in the clay-house. The slurry is added to



[Bell & Robertson Ltd., Aberdeen

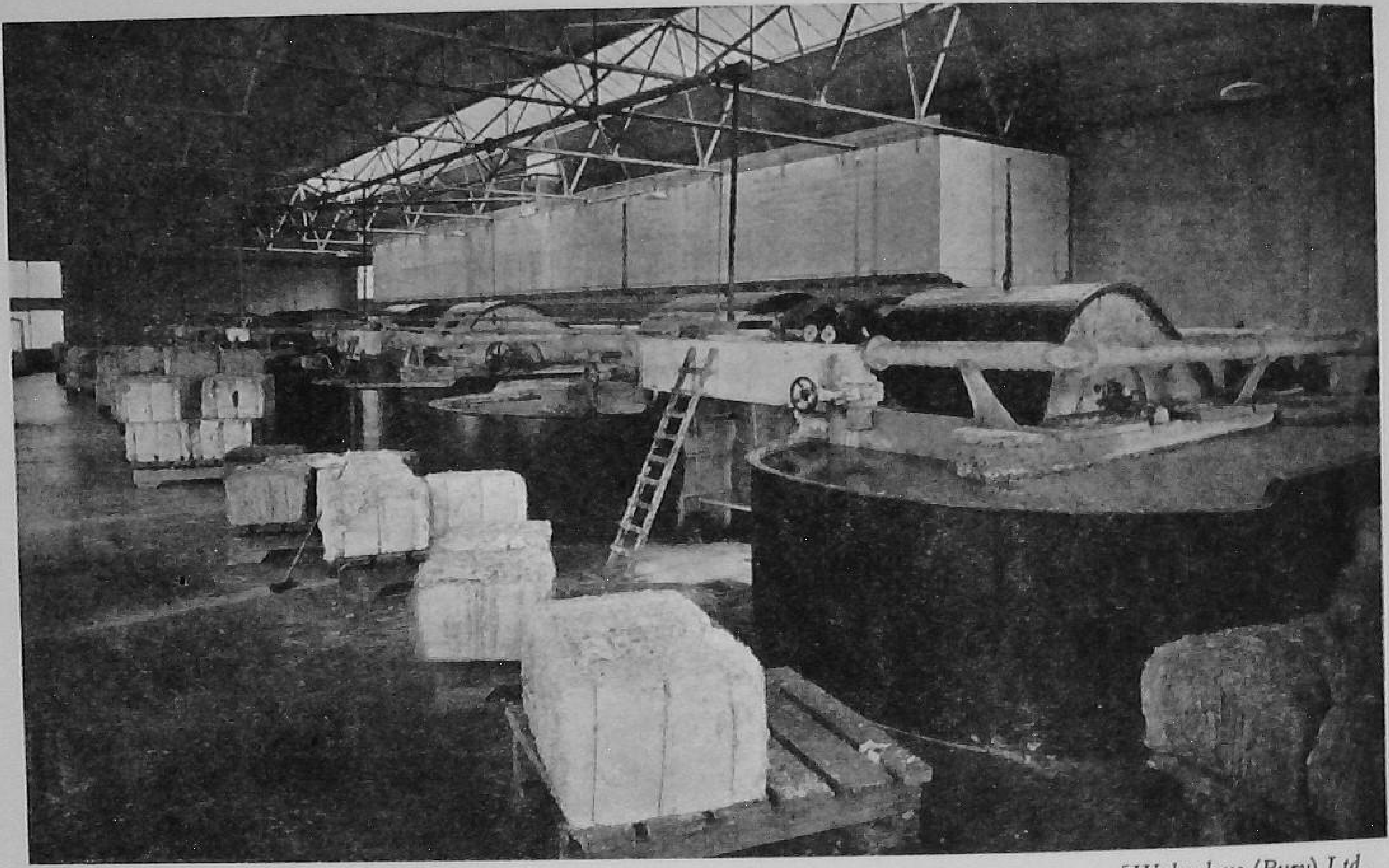
FIG. 192.—TYPICAL CLAY SLURRYING PLANT, SHOWING TWO MIXING TANKS FROM WHICH THE SLURRY FLOWS BY GRAVITY, THROUGH A DIRECT-DRIVEN ROTARY STRAINER, TO THE STORAGE TANK

the newsprint stock usually at the Trimbey or other form of proportioner. Alternatively it may be measured in boxes of suitable capacity, and added to the beaters.

Alum, either in the form of kibbled 17 to 18 per cent quality, or as 14 to 15 per cent slab alum, is dissolved in tanks having a perforated false bottom fitted quite near the top. The alum is loaded on to the false bottom, and water is run in until the solid alum is just covered. As the alum dissolves, the denser solution falls to the bottom of the tank, thus giving some natural circulation which helps to speed up the dissolving process. Sufficient alum is added to the tank to give a solution containing 2 to 5 lb. per gallon. A useful check of the concentration can be had by testing the solution with a Twaddell hydrometer.

From the mixing tank, alum flows by gravity to the storage tank, from

which pipe lines take it to the machines. The feed may be arranged discontinuously at the breakers or beaters, or continuously at the proportioner.



[Walmsleys (Bury) Ltd.

FIG. 193.—BREAKER AND BEATER FLOOR FOR THE PREPARATION OF STOCK FOR TWO MODERN NEWSPRINT MACHINES

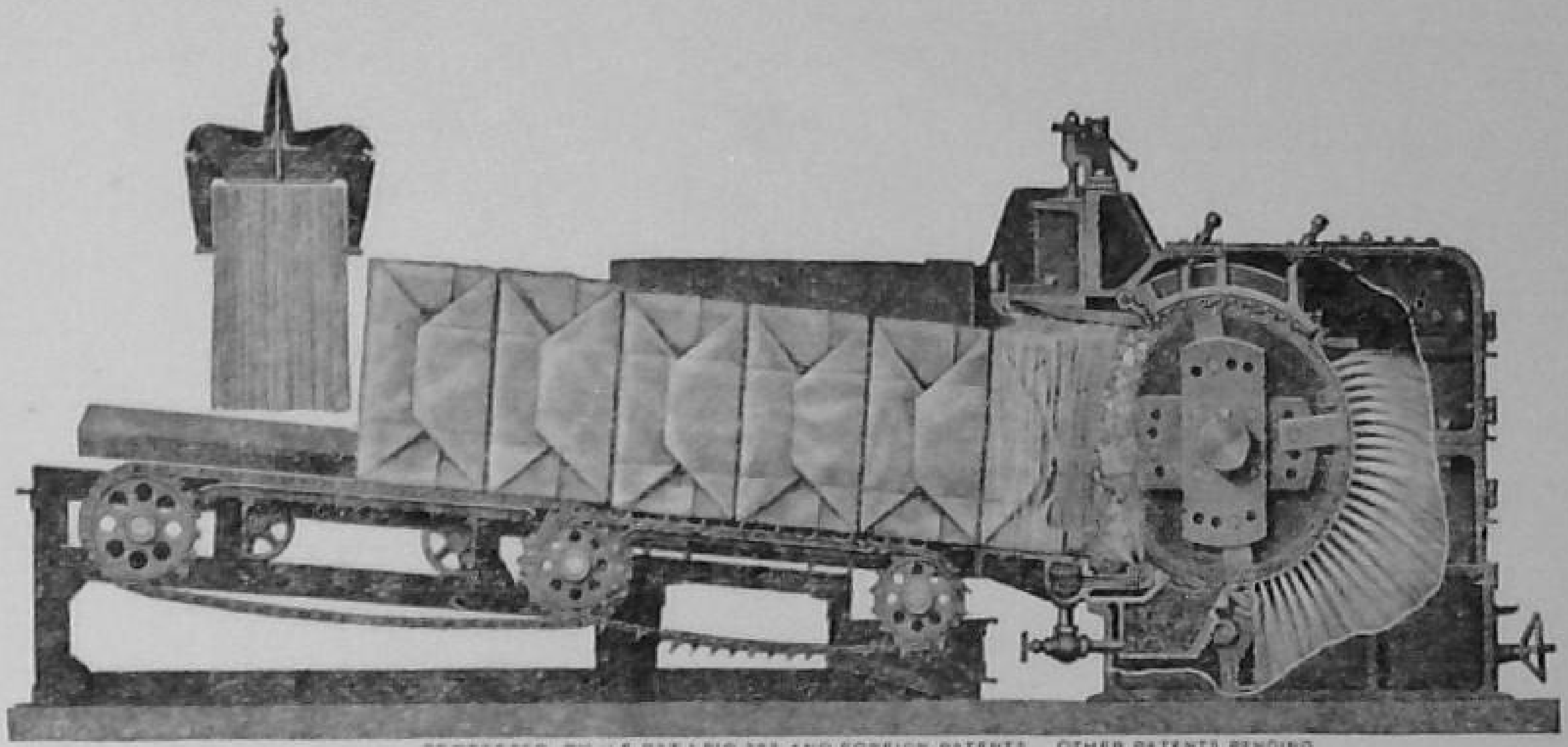
In some mills it has been possible to dispense with alum altogether, since it is now recognized that size is not required in newsprint. In general, however, troubles such as sticky presses are likely to arise if the stock is not kept down to a pH value of about 5.

Alum solution is a very corrosive liquid and must be handled in lead-lined or other suitably protected tanks and pipe lines.

The dyes used for newsprint are almost exclusively basic dyes because they are cheap, they are bright colours, they dye directly without difficulty and the fact that they are fugitive is of no consequence. In modern mills they are dissolved in bulk, and added to the stock at the proportioner. This is a clean and convenient method of dyeing, as the beater floor is kept completely free from dyes, and shades can be more quickly and easily controlled the nearer they are added to the machine itself.

Preparation and Properties of Stock.—The preparation treatment of baled pulp for making newsprint stock consists essentially in breaking up the laps and then disintegrating the fibres so that they are finally all separated from

one another in a uniform suspension ready to flow on to the wire of the paper-machine. There is little if any beating required.



[*Sturtevant Mill Co., Boston, Mass.*

FIG. 194.—STURTEVANT BALE PULPER

Accepted stock has to pass through the semi-circular screen plate.

The method of breaking that is still the most popular is to use the common type of breaker having a roll fitted with bars that are saw- or wavy-edged. The bars are usually equally spaced round the roll about 18 inches apart, and there is no bedplate. The roll operates in a fixed position about 6 inches above the bottom of the breaker trough, and it is not adjustable or counterbalanced like a beater roll. Breakers of this type for newsprint stock are built to hold about 1 ton (air-dry weight) of pulp at a consistency of 5 to 6 per cent, the capacity of the trough being about 4,500 gallons. Bales are fed by hand, a few laps at a time, into the breakers just in front of the roll, the filling operation taking altogether about 10 minutes. After a total period of 20 or 30 minutes, including filling in, the stock is sufficiently broken up to be dropped to the breaker chest.

Although this method of breaking appears, on the face of it, crude and unscientific, and represents no advance, other than in the capacity of the breaker, over methods that have been in use for very many years, it compares surprisingly well in labour and power costs, and in capital expenditure, with proposals made from time to time with a view to modernizing the procedure and reducing the amount of man-handling required.

Among these proposals may be mentioned the Sturtevant pulper, which is illustrated in Fig. 194. With this equipment, bales are mounted on a conveyor which carries them continuously to a revolving drum fitted with claws that tear at the surface of the pulp and effectively break it up. A shower

of back-water plays on the surface where disintegration takes place, and the resulting slush falls below into a breaker chest.

Another system, known as the Liebeck fibrator, is an attractive alternative to the generally adopted breaker method. In this arrangement, bales are packed together in line on a conveyor, but instead of being forced by the moving conveyor direct against a disintegrating roll, the pulp falls, bale by bale, into a large oblong concrete breaker chest capable of holding 5,000 lb. of stock at 3 per cent consistency. The chest is fitted with a horizontal shaft, on which are fitted large disintegrating propellers, and as the bales are fed in, they fall some 10 or 12 feet either on to the shaft itself, or on to stationary horizontal concrete baffles which protect the propellers. This heavy fall helps to split the bales into laps, and then the propellers thrashing round are very effective in breaking the laps down to slush form. These breakers require about 30 minutes, including loading time, to treat the stock.

Both the Sturtevant whole bale pulper and the Liebeck system are able to handle pulp that is difficult to disintegrate rather more satisfactorily than conventional breakers. Thus, the Liebeck breaker is able to handle frozen pulp without any prior hacking and man-handling of the bales to separate the laps. The Sturtevant pulper has been employed successfully to break up dry kraft, a task which is very difficult in an ordinary breaker. Both these methods of pulping, however, suffer from the disadvantage that labour is still required to load the pulp on to the conveyors, and to remove the baling wires. Perhaps for this, among other reasons, these newer methods have not displaced the breaker system to any appreciable extent for newsprint.

An arrangement for the breaking and preliminary treatment of pulp that has operated satisfactorily in several news mills in this country has been to have for each machine, making about 150 tons of paper per 24 hours, a battery of three 1-ton breakers for handling the groundwood, one 1-ton sulphite breaker and two 1-ton sulphite beaters. The beaters, unlike the breakers, are fitted with bedplates, but they do very little real beating, and chiefly help to disintegrate the pulp further. The groundwood breakers operate independently and discharge the stock into a common breaker chest. The sulphite breaker may be arranged to discharge the stock direct to a pump which transfers the stock to one of the two beaters, where the pulping treatment is continued for about an hour. The sulphite beaters then discharge the stock into a sulphite stock storage chest.

Groundwood and sulphite pulp are thus, in modern practice, broken and disintegrated separately in the early stages. The breakers, in each case, are fed with back-water obtained by gravity from the back-water storage tank,

and when the broken-up stock is let down into the storage chests, additional back-water is added to wash down the rather thick 5 to 6 per cent stock. This washing dilutes the stock to about 3 per cent, and in order to keep the concentration as constant as possible, the chests are allowed to fall always to the same level before the next breakerful is dropped. The addition of dilution water is continued via the breaker until the stock-chest level has been brought up to a predetermined level to give the required concentration of 3 per cent.

Storage chests for both sulphite and groundwood stock are usually rather long and narrow, the width being roughly the same as the height (see Fig. 181). They are fitted with a horizontal shaft to which are attached paddles, or propellers, to provide the necessary agitation to prevent sedimentation or flotation, and to help in some small way in the soaking and disintegrating process. For the sake of cleanliness, the tanks are permanently closed in with a manhole at the top through which access can be had for inspection and repair purposes. The capacity of these chests is usually sufficient, together with the refiner and machine chests, to give about 4 hours' supply of stock to the machine. The greater the capacity the better the opportunity there is to get the stock thoroughly mixed, which helps to maintain a uniform consistency. It also gives some margin in the event of any breakdown occurring in the breakers. On the other hand, a large chest-capacity makes it difficult to make any rapid changes of furnish, if this should be necessary.

The stock from the breaker and beater storage chests may be refined separately, then mixed, by means of a proportioner, in the ratio needed to give the desired percentage of sulphite. After mixing, the stock in most installations is refined again, and is then ready to be fed to the mixing pump to provide the dilute stock for the breast box.

No hard-and-fast rules can be laid down as to the exact flow-system needed to give the best refining results. Normally two or three refiners, each taking about 250 horse-power, will be installed for a machine making 150 tons of paper a day. From the evidence available, it seems that two refiners should be enough for the work to be done.

The purpose of refining, so far as newsprint is concerned, is primarily to complete the disintegration of the stock, which, after breaker treatment only, is full of undisintegrated clots of pulp. Refiners are able to clear these away completely. Groundwood changes little in freeness, or other characteristics, on being refined, although sulphite pulp, especially if it is added to the breakers in an air-dry condition, may increase in strength considerably when refined. This increase does not, however, seem to be of primary

importance, partly because the percentage of sulphite used nowadays is so low that its contribution to the strength of the finished sheet is rather small, and partly because the primary function of sulphite is to make full use of the long slender fibres to give wet strength to the immature sheet of newsprint, thus helping it to withstand the stresses set up in passing from the couch to the drying cylinders. Refining helps to some small extent to control the wetness of the stock on the wire, but there is no doubt that groundwood is rather unresponsive to refiner treatment, and therefore it is more important that the right quality of groundwood should be obtained from the pulp mill, rather than that any attempt should be made to try to modify its quality by treatment in the paper-mill.

The correct proportioning of sulphite and groundwood stocks is dependent upon the maintenance of a uniform consistency, and some reference has already been made both to the usefulness of large chests, and also to the importance of dropping breakers regularly and diluting the stock methodically in order to avoid excessive variation in consistency.

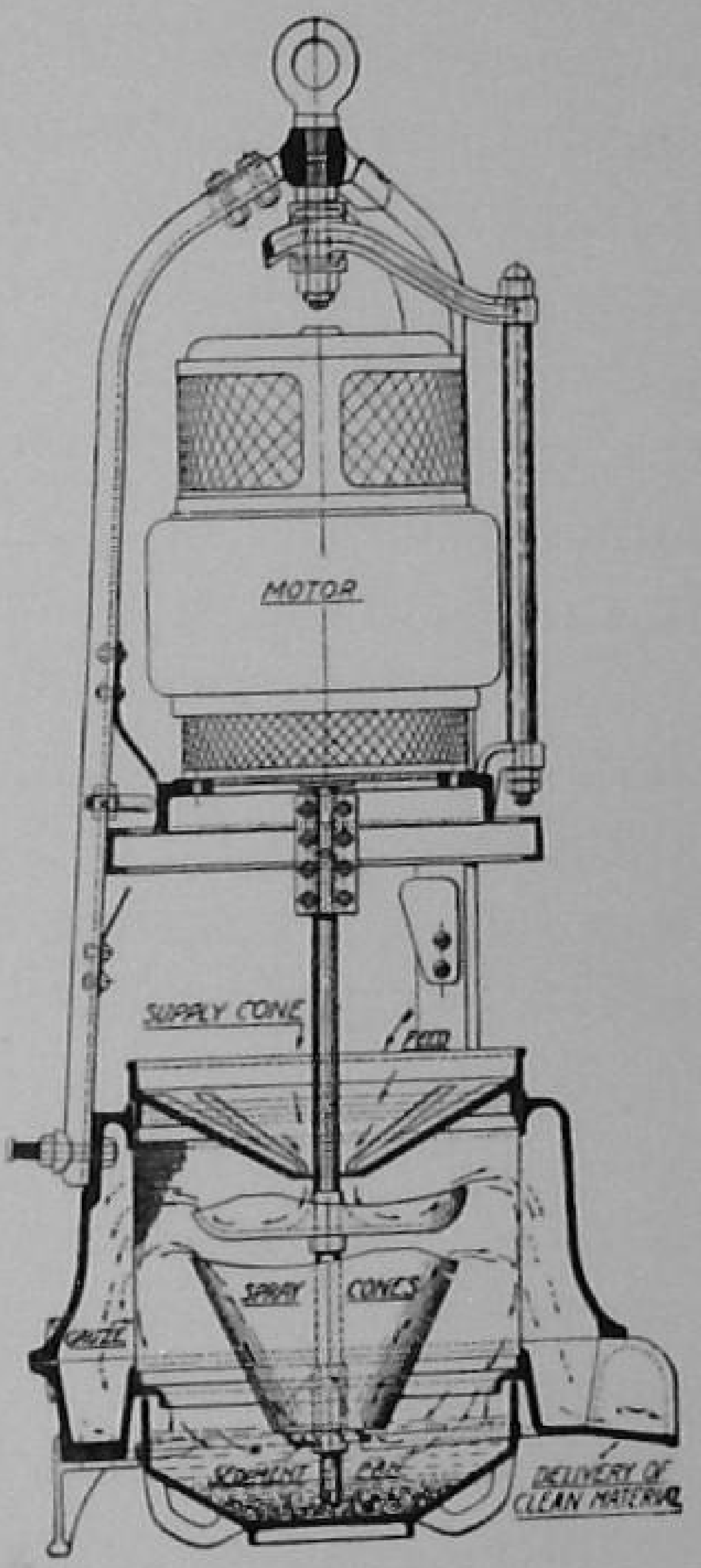
It may be found desirable, in addition, to control the stock automatically, using one of the many types of consistency regulator available for the purpose. All these regulators depend, for their operation, on the stock changing in viscosity, as the consistency changes, and although this relationship is rather variable, depending, among other things, on the kind of pulp and the treatment it has received, a well-designed and carefully constructed regulator can give a very satisfactory measure of control.

The separately prepared groundwood and chemical pulp stocks are mixed by means of a proportioner, of which a number of types and designs are available. These depend usually on the provision of a constant head of each kind of stock by pumping up to a receiver having an overflow for stock to return to the storage chest. From the constant head, or constant level compartment, the rate of flow of the stock is controlled by a revolving variable-speed paddle-wheel, as in the Trimbey proportioner, or by a rectangular weir having an adjustable width, as in the Tidbury proportioner. The two proportioned stocks are collected together in a receiver and conveyed by gravity to the mixed stock chest, from which the stuff is pumped for further refining and consistency control, finally being discharged into the machine chest ready for the mixing pump.

In modern mills, the proportioner is the place where, in addition to adjusting the ratio of groundwood to chemical pulp correctly, loading, dyes and sometimes alum are added, in the form of a suspension or solution. As in the case of pulp, the rate of flow may be controlled by a constant head of the liquid, coupled with a feeding paddle rotating at the rate required to

give the necessary dose. A more recent and very satisfactory method of obtaining a visual control of alum flow is to use a rotameter. This type of flow indicator consists of a very gradually tapering glass tube. A cone rises or falls in this glass tube, according to the quantity of liquid that has to escape between it and the glass tube; the greater the flow the higher the cone must rise to take advantage of the taper to give the required larger clearance between the glass tube and the cone. Rotameters are obtainable already calibrated over the range of flow-rate desired.

From the proportioner, then, the stock is complete with colour, loading and alum, and after further refining it is ready for the machine.



[The Watford Engineering Works Ltd.

FIG. 195.—THE ROTOSPRAY FOR CLEANING CLAY AND OTHER LOADINGS AND COLOURS. THIS ALSO HAS A HOMOGENIZER FOR SEPARATING THE PARTICLES AND GIVING AN EVEN FLOW OF CLEAN SLURRY

In dealing with the correct furnishing and preparation of the stock for making newsprint, stress must be laid on the importance of selecting pulps which are suitable for the purpose, and on the need for keeping out of the system foreign material likely to affect adversely the quality of the sheet, or cause breaks on the paper-machine. Methods of evaluating pulp quality have advanced very considerably during the past few years, and in modern newsprint mills the testing of the quality of shipments is an important part of laboratory control work. The tests made include freeness determinations, the estimation of shive content and the preparation and examination of laboratory sheets. Detailed information about methods of this kind is available in the technical literature and in the reports of committees which have made a special study of the subject.

The precautions taken to prevent foreign matter getting into the paper consist firstly in keeping a careful control of the cleanliness and general condition of all pulp used; this is usually done when the pulp is first received at the mill and is tested for moisture content. Secondly, coarse grids are fitted at various points in the pipe lines, in boxes which may be isolated and cleaned out periodically without interrupting production. The final point for holding back unwanted material is at the strainers through which the stock passes immediately before flowing to the breast box.

Strainers and Slice.—The finally prepared stock, regulated to a uniform

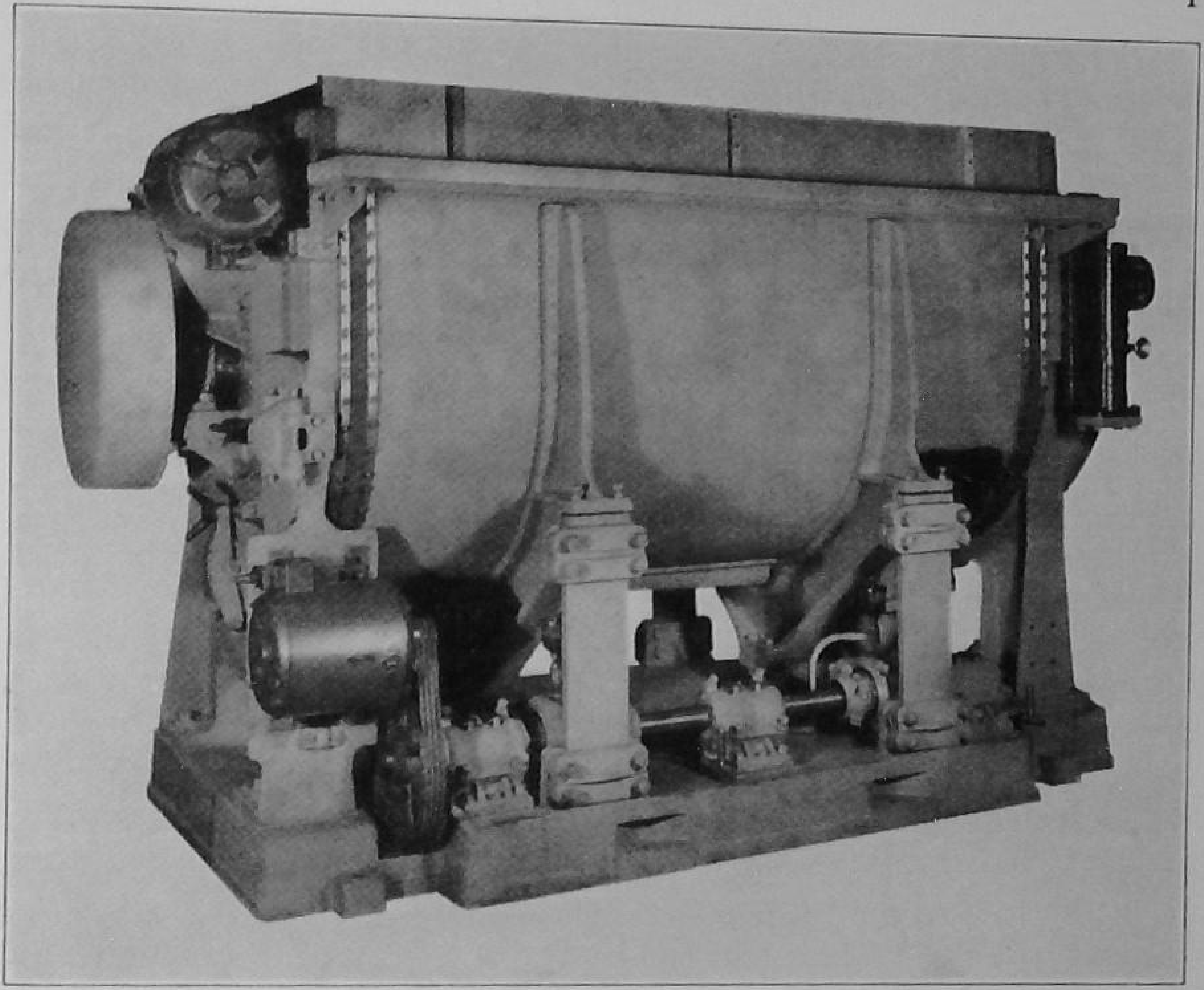
consistency of $2\frac{1}{2}$ to 3 per cent, and containing dyes, alum and loading, is pumped to a head box, from which the required quantity of stock flows through the stuff valve to be mixed at the mixing pump with the back-water recovered from the wire pit. It is important to have a constant pressure of stock behind the stuff valve, as this is the valve that is used for controlling the basis weight of the paper being made. The valve itself should preferably be specially designed so that a large number of turns are required to change the setting from the shut to the full-open position. This will give greater delicacy of control, and therefore more accurate basis weight adjustment than can be obtained from a valve that requires only a few turns to produce a large change in the rate of flow. The diluted stock from the mixing pump passes direct to the strainers which, usually, are located behind the breast box.

The strainers needed for news stock must, of course, be of large capacity. The type used (see Fig. 196) is that known as the inward-flow strainer, because the stock is pumped to an outer container and flows by gravity through the slits of the screen to the centre. The screen itself is a large cylinder in which thousands of slits, parallel with one another and in rows, are cut. The usual width of slit for news is about 0·0025 inch. In operation the stock is helped through these narrow slits by the jogging motion of the outer half-cylindrical container, which is flexibly coupled to the main framework of the strainer by rubber jointing each end. Material, such as coarse shives and slivers, which is rejected by the screens, will accumulate in the outer jogging container. It may be removed by bleeding continually a small quantity of stock from the bottom of the container and passing it to an auxiliary screen, where accepted stock is returned to the wire pit, and rejected material is sent to the main drain.

A large machine producing 150 tons of newsprint a day will require four strainer units mounted parallel to each other and parallel to the direction of the machine. The screened stock is discharged from the strainers into the flow box which leads it over various baffles and weirs to the slice (see Fig. 197). In the single case of the world's largest paper-machine, making 200 tons or more of paper per 24 hours, there are six strainers all arranged at right angles to the direction of flow, in two lines of three, on either side of a central collecting trough.

The art in designing efficient flow (or breast) boxes consist firstly in aiming at keeping the stock as uniformly dispersed as possible; secondly, in preventing, as far as possible, eddy or other local disturbances from arising, and lastly, the stock must be projected on to the wire at a speed which gives the most desirable sheet formation and sheet properties generally. The

optimum speed of projection is of course intimately bound up with the wire speed. Normally it is found that the best practice is for the stock to be pro-



[Vickerys Ltd. and Walmsleys (Bury) Ltd.

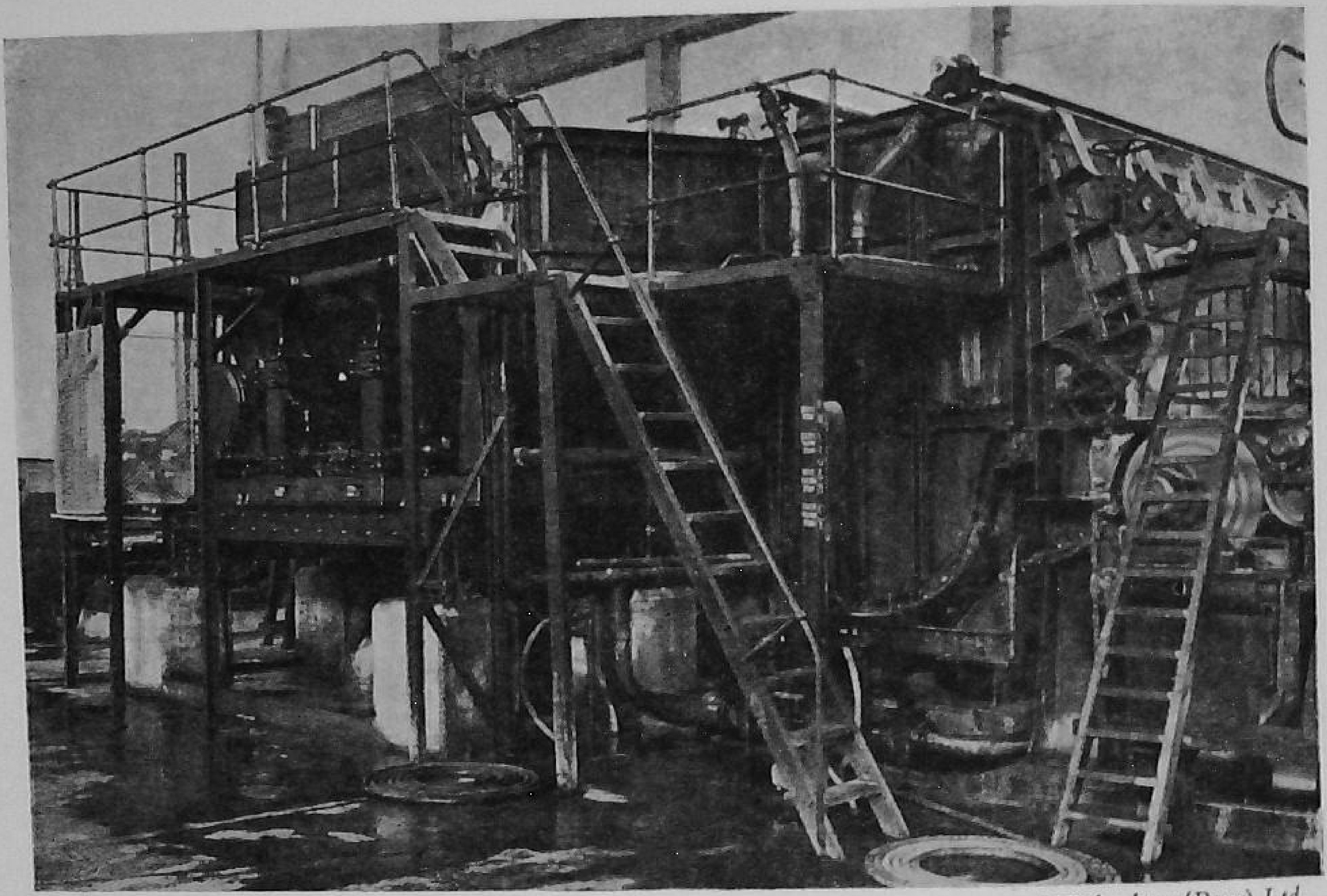
FIG. 196.—LATEST TYPE OF HIGH-CAPACITY BIRD SCREEN FOR NEWSPRINT STOCK

The lower motor operates the shake motion and the upper motor drives the gearing which keeps the cylindrica screen turning slowly round.

jected at a rate which is 5 to 10 per cent slower than the speed of the wire. Flow boxes must, of course, have no dead spots where slime and dirt can accumulate; a clean design, in this respect, is consistent with the need for producing a uniform rate of stock-flow to the slice.

The so-called projection slices (see Fig. 198) are used almost without exception in high-speed news machines, although there are one or two other kinds of slice working on different principles, and these may one day modify newsprint slice technique. There is, for instance, the Millspaugh arrangement, in which the stock contacts directly with a suction-operated forming cylinder. This arrangement, incidentally, has the advantage of dispensing with the conventional wire part of a paper-machine. Another interesting development is the pressure slice in use in one or two mills in the U.S.A. In this arrangement the wire itself forms the base of a kind of swan-necked

breast box. The stock impinges on the wire and is to some extent forced down against it, giving an immediate initial mat of fibres on the wire. The



[*Walmsleys (Bury) Ltd.*

FIG. 197.—A TYPICAL STRAINER, BREAST BOX AND PROJECTION SLICE ASSEMBLY FOR A LARGE NEWSPRINT MACHINE
On the left, the flexibly-mounted container of one of the four inward-flow cylindrical screens can be seen.

quantity of stock available for building up the remainder of the sheet thickness is governed by the height of the projecting slice 'lip' above the wire. This slice is being found especially useful for very free stock.

The Wire Part.—The wire part of a news machine is different from that of slower-running machines in that there is usually no shake fitted, the section is removable as a whole to facilitate wire changing, and it has fewer table, or tube, rolls.

When the stock flows on to the machine wire, drainage of the water commences right away, but only a small proportion is removed by the effect of gravity alone. Most of the water which is removed before the suction boxes are reached is withdrawn by the effect of the contact of the table rolls with the underside of the wire, and by the suction produced as they revolve rapidly round. This can be seen by observing what is happening under the wire, and also to some extent the action is indicated by the appearance of the stock on top of the wire.

The very large volume of water handled at the wet end of a news machine

makes it necessary for the table rolls to be rather large in diameter. On a 220-inch machine the diameter would be 11 or 12 inches, while on a 300-

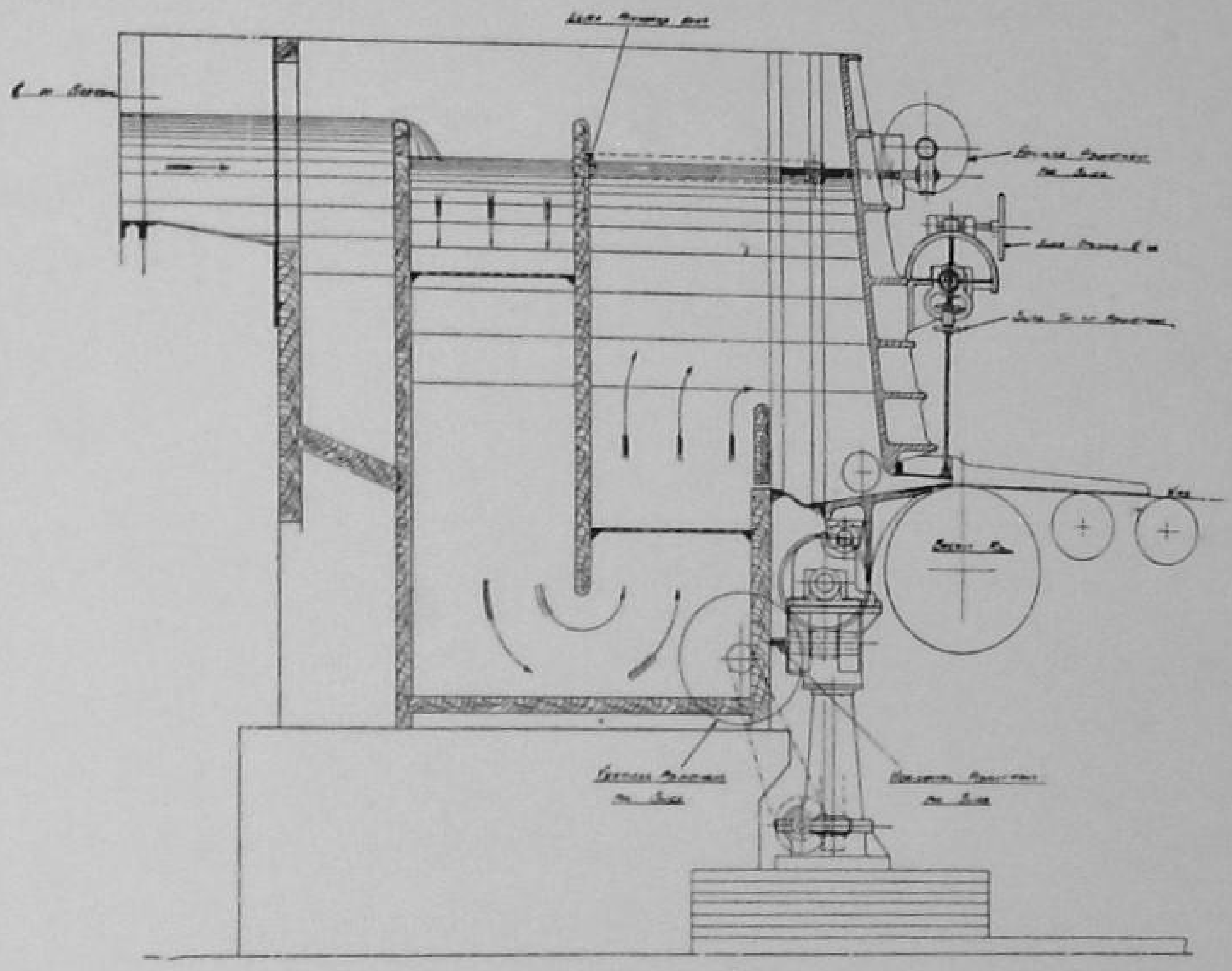


FIG. 198.—SECTION THROUGH A TYPICAL FLOW BOX AND SLICE FOR A HIGH-SPEED NEWS MACHINE

inch machine the diameter is 15 inches. This large size is also needed to prevent whip at the high speeds at which the table rolls rotate.

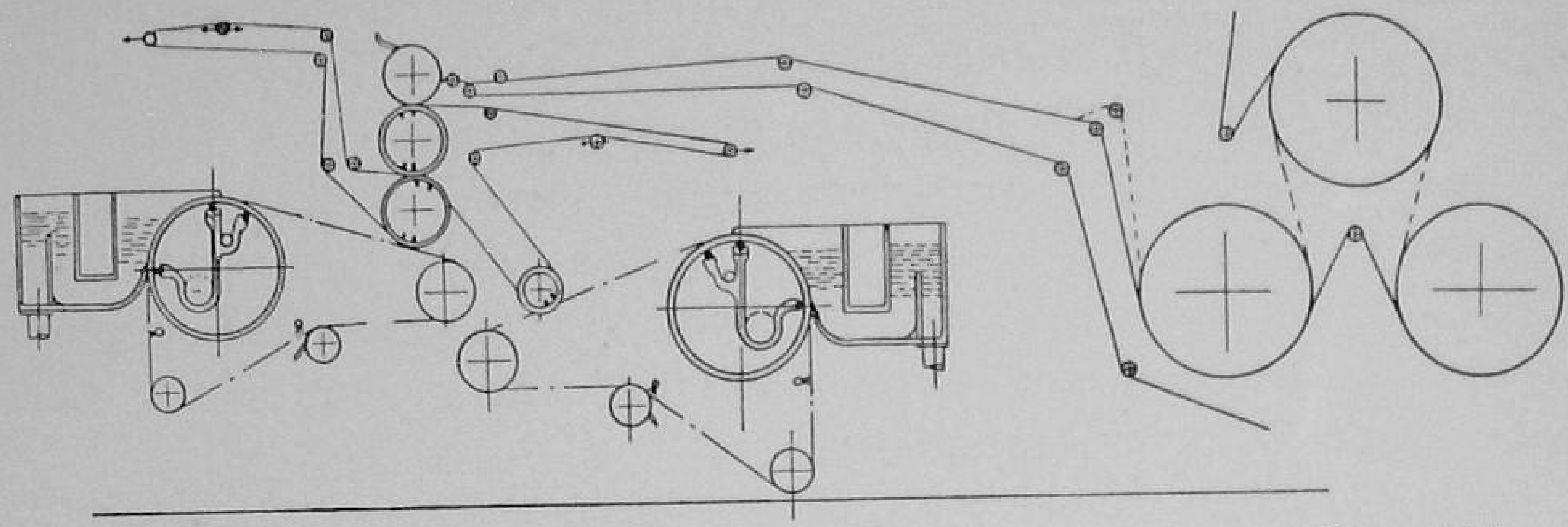
Some of the water drained from the stock tends to be flung back on the underside of the wire by the centrifugal action of the rolls. This can spoil the formation of the sheet, and in order to prevent the trouble the practice is very often adopted of fitting baffles between the rolls, especially near the breast roll. Alternatively, it is helpful to space the rolls fairly far apart.

The wires used for making newsprint are almost invariably about 60 meshes per inch in the cross direction and 40 in the machine direction, and the recently developed long crimp or twill wires are used very extensively for news.

Drainage on the wire increases the consistency of stock from about 0·8 to about 3 per cent, at which point the suction boxes or flat boxes, as they are sometimes called, come into action, raising the consistency to around 16 per cent. Finally, the remaining water, which is capable of being removed while the sheet is still in contact with the wire, is taken out by the couch where the concentration is increased to about 20 per cent.

The finally diluted stock fed to the flow box of a newsprint machine is very heterogeneous. The freeness will be about 50 c.c. Canadian standard, and the china clay will account for about a quarter of the 0·8 per cent of

total solids, if an average ash content of about 8 per cent is desired in the sheet being made. The quantity of very fine fibre and clay present in flow-box



[Millspaugh Ltd.

FIG. 199.—ARRANGEMENT OF MILLSPAUGH DUPLEX VACUUM-FORMING MACHINE WITH STACKED SUCTION PRESS

This machine has no slice, the wires are very short, and the duplex sheet is made by combining the undersides of the two webs, thus giving finished paper having two top sides.

stock is very much higher than it is in the thick stock delivered to the mixing pump. This stock will have a Canadian freeness figure of about 125 c.c., and the total solids will have a china-clay content of about 10 per cent.

The reason for the change in the composition and properties of the stock when it gets to the flow box is that an amazingly large proportion of the stock that flows on to the wire passes through the meshes by drainage and by the action of the table rolls. Flow-box stock having a consistency of 0·8 per cent will give rise to an average consistency in the wire pit of about 0·3 per cent. This means that nearly 40 per cent goes through the wire. Most of this fine short-fibred stock goes back again to the mixing pump to be delivered once more to the flow box. It therefore does not represent lost material, but its circulation back into the flow box is the reason why the stock issuing from the slice is so very different in properties and composition from the thick stock fed to the mixing pump.

The number of suction boxes fitted to the wire will usually be about eight, and the suction will be graded from about 5 inches of mercury to about 10 or 12 inches. The tops of the boxes must be fitted with some material that will give rise to as little friction as possible between the rapidly travelling wire and the suction boxes. Many different materials, including glass, granite and synthetic resins, have been tried, but by far the most popular is still wood. A hard wood, such as maple, arranged so that the grain is perpendicular to the wire, gives very satisfactory results, both because it requires attention less frequently than horizontal-grain suction

boxes, and also because the load on the couch motor is reduced to a minimum.

A dandy roll is usually run, even on the fastest news machines in the country. It closes the sheet and gives a more uniform look-through. Incidentally, a dandy roll enables an identifying water-mark to be applied.

The couch on a modern news machine is essentially of the suction type (see Fig. 128), otherwise economical speeds cannot be attained. Occasionally a light rubber-covered top couch roll is used as well, but opinion is divided as to whether this is really helpful. The vacuum at the couch is usually about 17 inches of mercury.

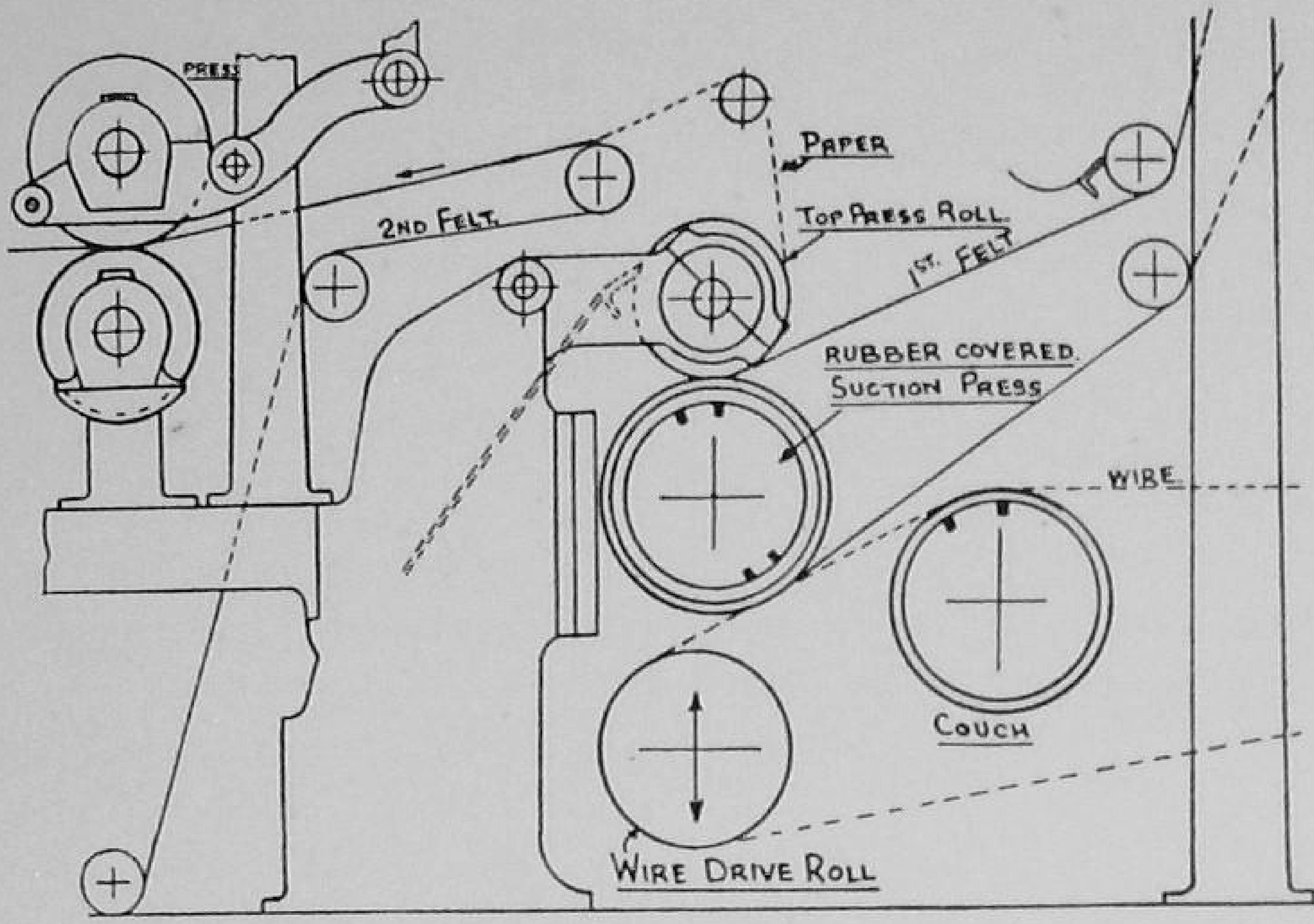
The Press Part.—During recent years quite a number of proposals have been made with a view to improving the pressing of newsprint.

Some years ago it was quite common practice to have two plain presses followed by a reversing third press, all with felts. Nowadays the first two presses are almost invariably suction presses; the third press, in the development of modern practice, was first deprived of its felt, then, by putting the brass roll at the bottom and the granite roll on top, it became a straight-through smoothing press. Finally, tests showed that it had very little, if any, effect at all on the finish of the sheet, so that, in present-day installations, there is usually no third press at all.

The bottom rolls of both first and second presses may be rubber-covered or just plain brass. Rubber-covered rolls have the advantage that they widen the contact at the nip, thus giving less drastic treatment to the paper. The rubber covering is also kinder to the felts, which are prevented from directly contacting the perforated brass roll. In some installations, notably on better-class paper-machines, running at slower speeds than news machines, important increases in wet felt life have been obtained, but for newsprint made at high speeds, rubber-covered press rolls are not invariably chosen, because improvement in felt life has not in all cases been established, and also because the extra length of the drilled holes makes quite an appreciable difference to the capacity of the vacuum pump required.

Two other important developments in pressing, to which reference must be made, are the stacked press and the dual press. In the stacked press three rolls are arranged vertically above one another. The two bottom rolls are perforated suction rolls, each having a felt, and the top roll is granite. The sheet is transferred from the bottom roll to the middle roll by a suction box, and there is, in addition, a suction box at each of the two nips for removing water. Pressure is applied in the conventional way by lever systems.

In the dual press (see p. 288) there are again three rolls together, but in this case they are horizontal. The solid roll is in the centre, and the two



[*Millspaugh Ltd.*

FIG. 200.—DIAGRAM OF MILLSPAUGH AUTOMATIC COUCH WHICH ELIMINATES THE DRAW BETWEEN THE CONVENTIONAL COUCH AND FIRST PRESS

perforated rolls are on each side. The dual press makes the arranging of the felts and the disposal of the water, thrown out centrifugally by the rolls, rather more simple.

The stacked press and, more especially, the dual press are logical developments of the press part, the most important advantage of which is the saving in space. This is a specially helpful feature when old machines are to be modernized (see Fig. 133), but it is doubtful whether a newly-planned newsprint machine would necessarily have a dual press installed in preference to two separate suction presses.

Other developments at the wet end of news machines have been concerned with handling the sheet in such a way that stretch is eliminated or greatly reduced at the draws. The stacked press and the dual press are themselves examples of this. The name of Millspaugh is especially connected with developments along these lines, and among his many interesting designs there is the automatic couch (Fig. 200), which picks the sheet off the wire by suction, thus eliminating altogether the draw from the couch to the press rolls.

Some indication of the importance of eliminating draws in this way may be obtained from the following figures, which have been carefully

measured at different points on a modern news machine fitted with a suction couch and two separate suction presses:

	Speed f.p.m.	Speed Increase f.p.m.	Stretch Per Cent
Couch	1,045	—	—
First press	1,108	63	6·0
Second press	1,120	12	1·1
First drying cylinder	1,129	9	0·8
Sweat cylinder	1,130	1	0·1
Pope reel drum	1,130	0	0·0
Total wet end stretch	—	84	8·0
Total dry end stretch	—	1	0·1
Grand total for whole machine	—	85	8·1

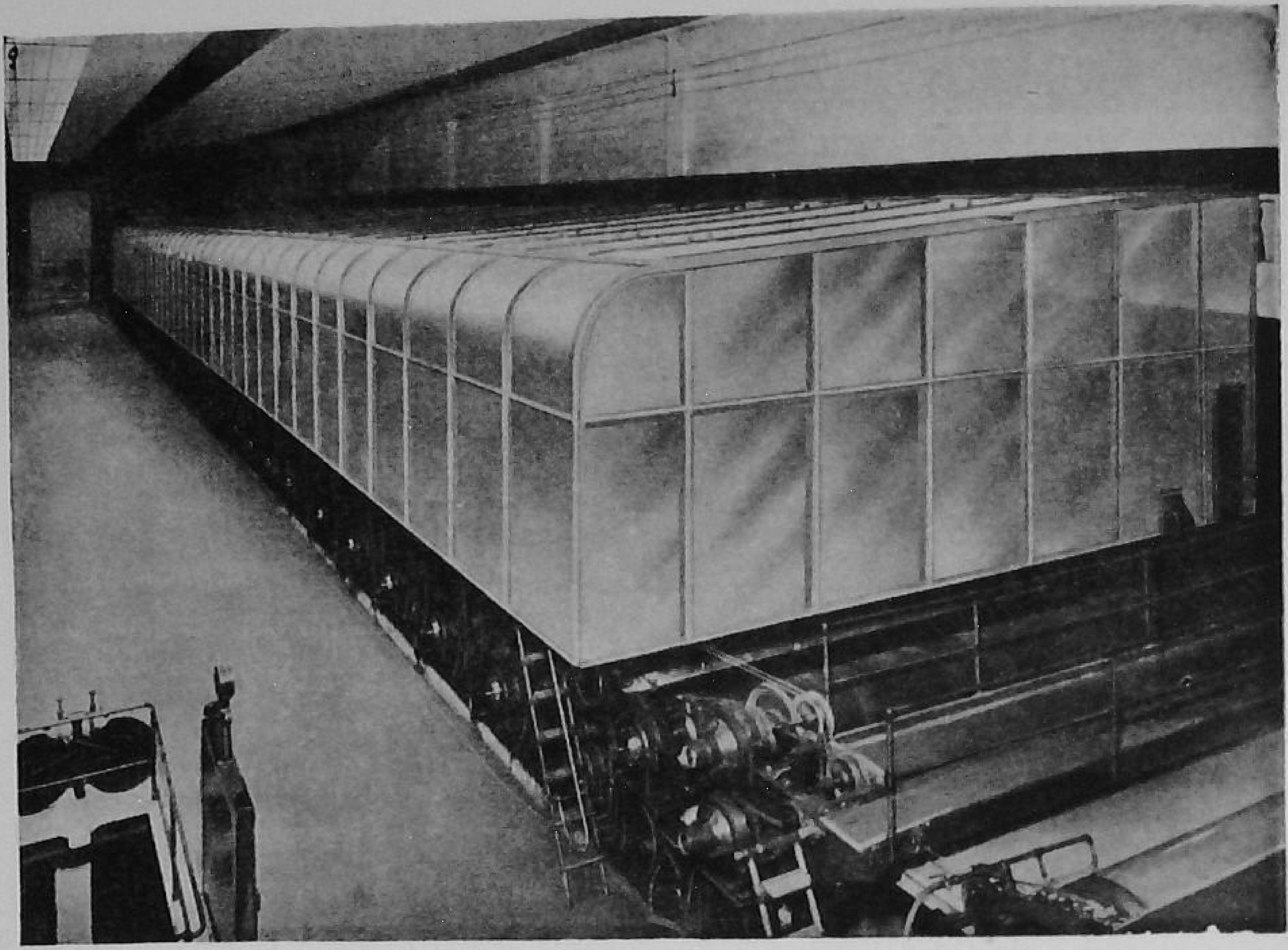
The moisture removed by a modern press part is indicated by the following average figures:

	Moisture Content Per Cent	Vacuum Used Inches
Couch	79	16
First press	68	17
Second press	66	22

Obviously it is important to remove as much moisture as possible by pressing, in order to reduce the amount of drying required to a minimum.

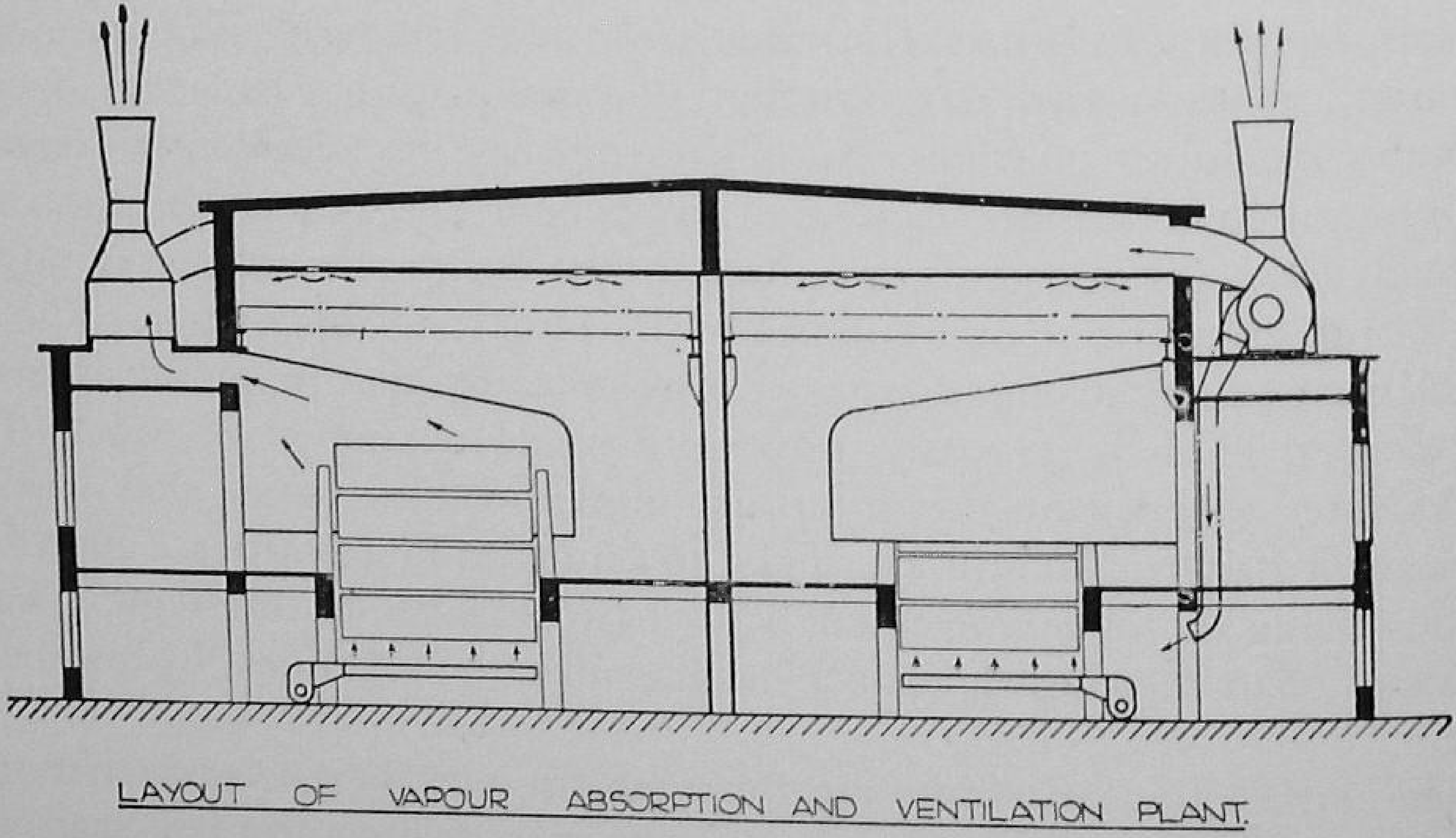
The Dryer Part.—The most difficult problem in the drying of newsprint is ventilation. The greater the width of a machine the greater is the difficulty of removing the moisture-laden air uniformly across the machine. It is the general practice to fit hoods by means of which the damp air is collected and discharged to atmosphere by a battery of usually six to eight fans situated above the back of the machine. Coupled with this system, hot air is blown in through trunking under the dryer section. The fundamental defect of methods of this kind, however, is that air cannot pass directly upwards past the drying cylinders because of the felts and the paper itself. Various methods have therefore been tried to promote adequate circulation between the cylinders, and the Grewin system is a typical example. In this system relatively small quantities of hot air are blown into the dryer section alternately from the front and back of the machine. The nozzles are placed as near to the paper as possible, so that fresh dry air may be brought continuously into contact with it.

In spite, however, of all the attempts made to improve the uniformity of drying, it is all too frequently necessary to have to try to compensate for uneven evaporation by loading the presses or crowning them specially to give the lowest moisture content in that part of the sheet where the drying is least efficient.



[Air Control Installations Ltd.

FIG. 201.—VIEW OF A NEATLY DESIGNED HOOD FITTED OVER THE DRYER PART OF A LARGE NEWSPRINT MACHINE



[Air Control Installations Ltd.

FIG. 202.—DIAGRAM ILLUSTRATING THE CIRCULATION AND REMOVAL OF AIR IN THE DRYER PART OF A NEWS MACHINE
Note the arrangement by which air is admitted to the machine-house roof to prevent condensation.

In tackling drying problems on news machines the fundamental fact must be kept in mind that practically all the moisture has to be removed by using

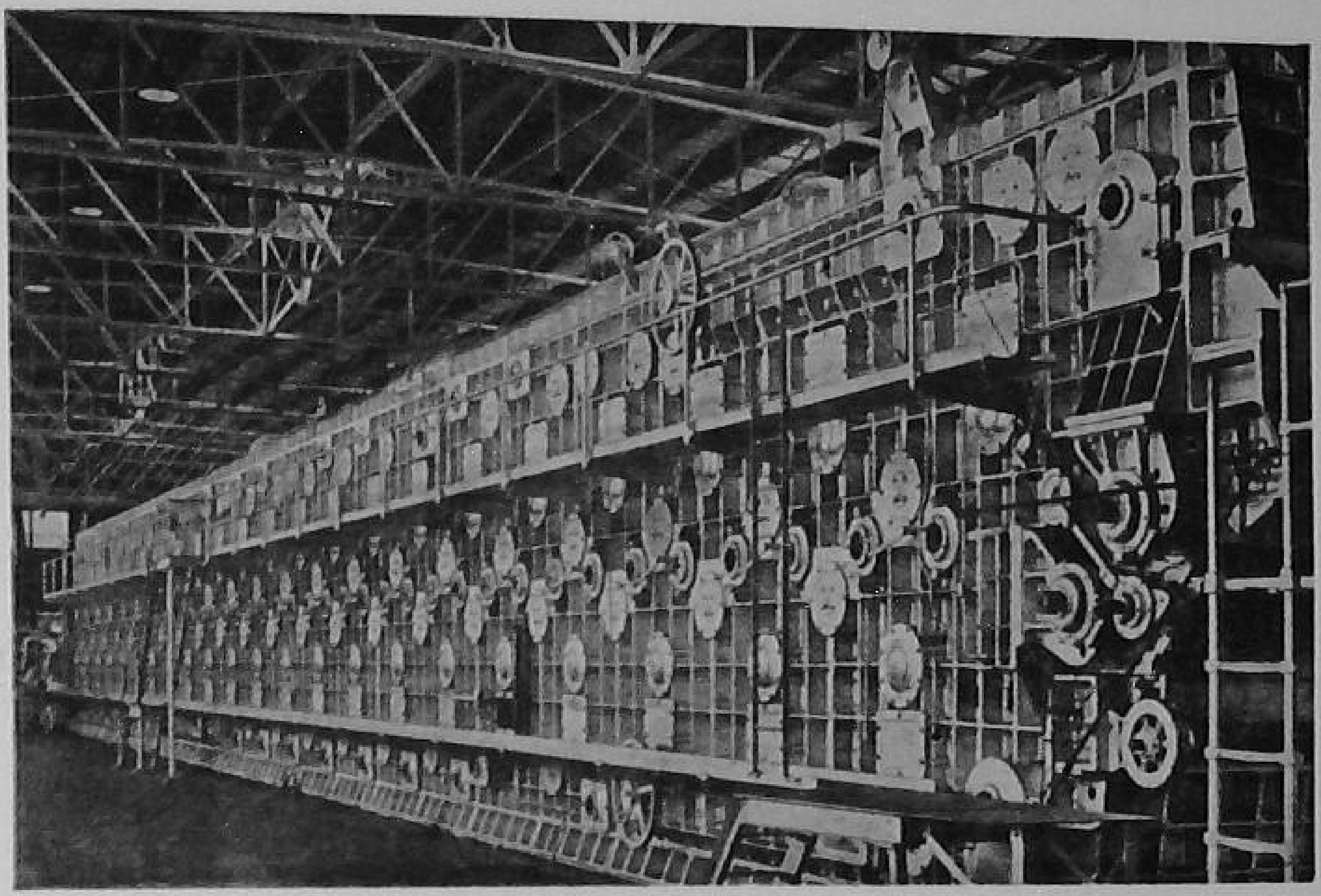


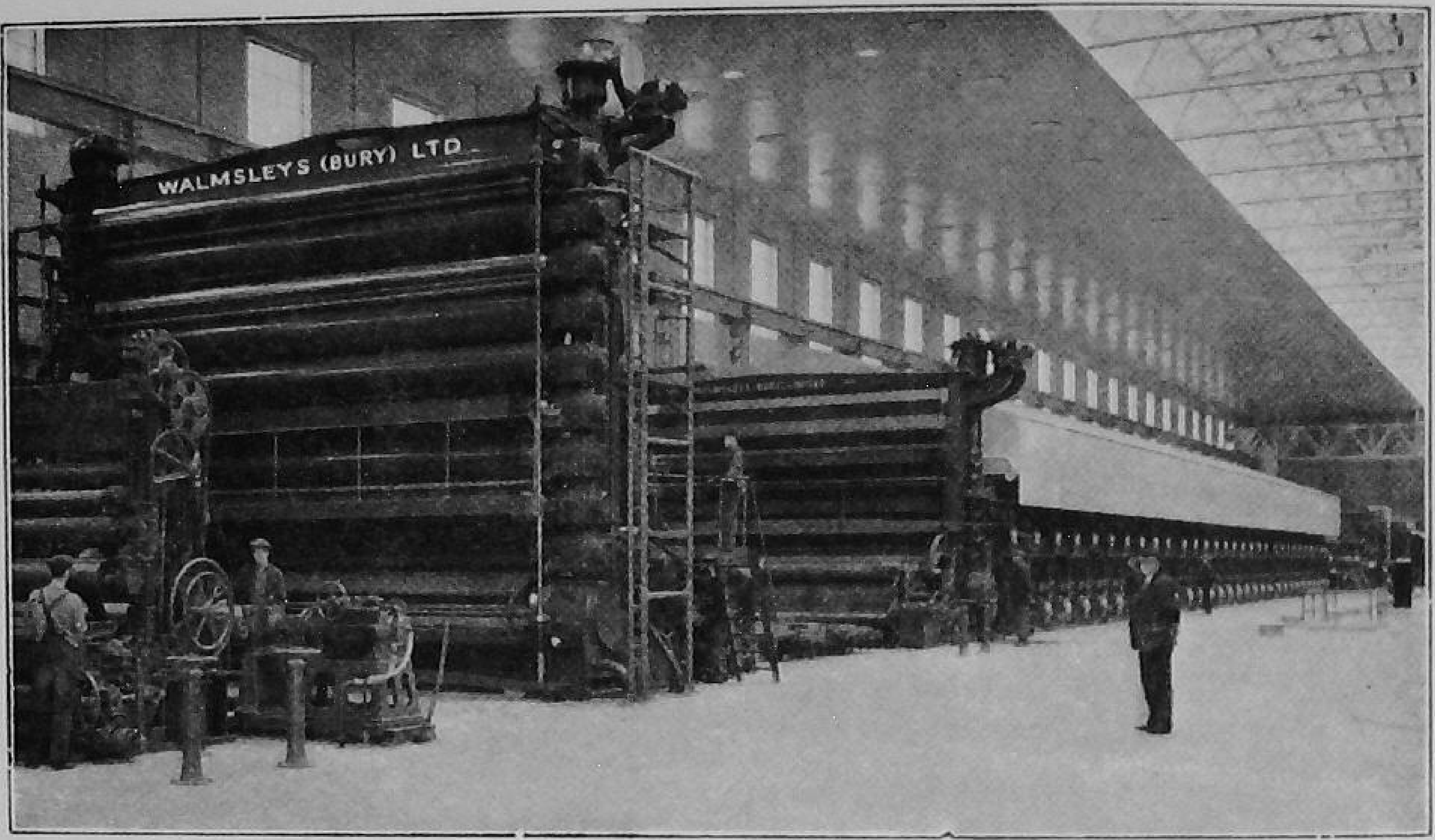
FIG. 203.—VIEW OF THE DRY END OF A FOURDRINIER MACHINE EQUIPPED WITH A MINTON VACUUM DRYER

air as a carrier. Water dissolves in air, and the higher the temperature of the air, the greater the quantity of water it can carry without becoming saturated. This mechanism of drying is entirely different from drying by ebullition, and it is doubtful whether any substantial proportion of the water removed from the sheet in a news machine is boiled off. Adequate supplies of hot air efficiently circulated and removed after becoming saturated, or nearly saturated, are therefore essential for satisfactory drying.

News machines built to run at the high speeds prevalent to-day are usually equipped with about fifty, or in exceptional cases as many as sixty, 5-foot dryers. It is generally considered that felt dryers are not an advantage, although there is some difference of opinion on this matter. The last cylinder is usually arranged as a sweat cylinder for damping the underside of the sheet. This is especially important when making M.F. paper. Dry felts are used throughout the dryer section, with the exception that on some machines it has been found beneficial to omit the first bottom section felt, the idea being that free movement of air past the sheet, at this stage, is more important than pressing the paper hard against the cylinders by means of a felt.

The difficulties of arranging for uniform ventilation, and therefore uniform drying, in conventional dryer parts, were overcome a few years ago by the introduction of the Minton vacuum dryer. Although very few paper-machines have been fitted with this rather expensive system, the experiment

was a very courageous one, and recently it has been applied successfully for pulp drying. In the Minton dryer all the cylinders are enclosed, so that they



[*Edward Lloyd Ltd. and Walmsleys (Bury) Ltd.*

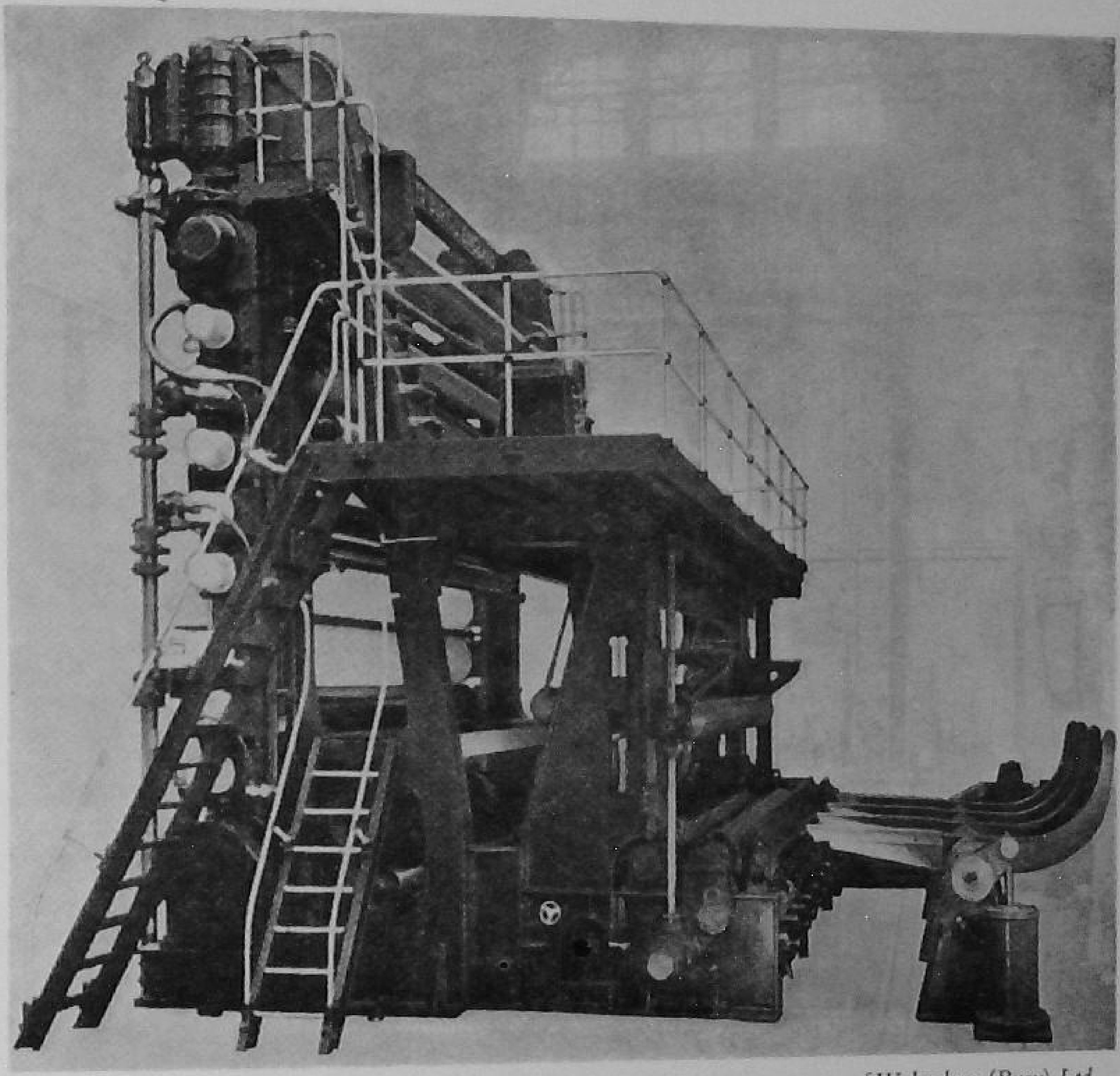
FIG. 204.—VIEW OF THE WORLD'S LARGEST PAPER-MACHINE

operate in a large air-tight compartment where the pressure can be reduced to about 7·3 inches of mercury. Working under these conditions, water can be boiled off, and thus no air circulation is required. Drying is therefore quite uniform provided the sheet is uniformly heated on the drying cylinders. Newsprint made on machines fitted with Minton dryers is more bulky and absorbent than ordinary newsprint, and it takes the ink very well.

Finishing.—Newsprint made in this country has achieved a very high standard of quality, and one of the factors responsible for this is the super-calender. To obtain the best results from the super-calender the moisture content has to be carefully controlled. Because of the difficulty, already referred to, of drying paper really uniformly, it is necessary to over-dry slightly, and then to damp the paper to the desired moisture content to give the best results from the super-calender. It is difficult to give any very definite figures for moisture content, but normally, after drying and before damping, there should be about 6 to 8 per cent of moisture in the sheet, and the finished paper should contain at least 8 per cent of moisture.

The paper is damped on the machine just before reeling. A spray damper is used to moisten the top of the sheet, and the automatic reel change-over drum provides a ready means of applying moisture to the underside, the

method being to spray the surface of the drum so that there is a film of water on it ready to be transferred to the paper.



[Walmsleys (Bury) Ltd.

FIG. 205.—VERY LARGE SUPER-CALENDER AND RE-REELER COMBINED, FOR NEWSPRINT

Newsprint super-calenders are remarkable chiefly for their gigantic size coupled with the fact that the accuracy with which the rolls are ground is sufficient to enable a sheet some $\frac{3}{1,000}$ inch thick to receive an amazingly uniform finish (see Chapter XXV).

Future Trends of Newsprint Manufacture.—In this very brief review of some of the salient features of newsprint manufacture, some indication has already been given of the lines along which developments are occurring.

Undoubtedly one of the main trends in technical advance will be towards further increases in speed. The scientific staffs of some of the leading companies are already actively studying the conditions and problems that will arise at speeds of 2,000 f.p.m.

Further efforts to cheapen the cost of production will be directed towards decreasing, still more, the proportion of chemical pulp in the furnish. This effect will be materially aided by further studies of groundwood production

with a view to producing qualities better suited to high-speed operation, and at the same time giving paper of adequate strength and good printing qualities. The processing of stock, in general, may in the future derive benefit from the application of modern preparation plant, such, for example, as the Sutherland refiner, which is very economical in power consumption.

Finally, although this chapter has been concerned primarily with the newsprint industry in this country, some reference must be made to the recently announced commercial production of newsprint from Southern Pine. This is a project that has long been under consideration, but difficulties due to the nature of the wood—particularly its high content of resins—have demanded many years of painstaking investigation to make the project a commercial possibility. The advantages of being able to use trees which grow to maturity in a dozen years or so have been a very attractive goal in developing this undertaking, and the new factory now in operation near Lufkin, Texas, may well be the forerunner of an important Southern newsprint industry.

CHAPTER XXII

HAND-MADE PAPER

THE making of paper by hand is unique in this respect, that it is still carried on in practically its primitive form, side by side with the most highly developed paper-making by machinery. When we look for the reason for this state of things, we find it in the very high quality and excellence of hand-made paper compared to machine-made for certain special papers, such as drawing and filter-papers, bank-notes, and superlative qualities of writing and account-book papers, etc. This is shown by the many attempts made to give to machine-made papers the qualities or appearance of hand-made by cheaper methods.

Hand-made paper is generally made from the best grades of linen and cotton rags. Papers for very special purposes are made from new rags. The reason for this is that the process is very costly, and it would be poor policy to put low-grade stock through such a process.

The rags are treated in much the same way as for machine-made paper, but as the quantities to be dealt with are very much less, they can be allowed more careful sorting and more time for treatment than is the case where machines have to be kept supplied.

These high grades of rags require very light treatment in boiling and bleaching, and the resulting paper is, or should be, of very high quality and purity.

The boiling is usually carried out in open pans without pressure, very little lime or caustic soda being used, so that most of the original strength of the fibres is retained.

After boiling, the rags are picked over again to remove any 'contraries' such as black threads, buttons, etc., which may have become exposed during the process.

The rags are broken in, in breakers fitted with drum washers to carry off the dirty water, clean water being run in all the time until the water leaving the breaker is as clean as that entering it. The colour of the stuff is then improved by adding a little bleach, which is afterwards carefully washed out, until a starch iodide test shows no trace of chlorine in the stuff.

When we come to the beating, which is done in small Hollanders with very light rolls, we find that longer and freer stuff, and also more highly fibrillated or wet stock, can be more successfully dealt with by hand than on

the ordinary Fourdrinier machine. For instance, for filter-paper, stuff that is so long, raw and free that it is impossible to get it through most strainers or to put it together on the machine wire can be made into a compact sheet by hand. And very highly fibrillated stock for strong ledgers, etc., can be made to heavier substances on the hand mould than could be run satisfactorily over the usual wet end of a Fourdrinier machine.

On leaving the beater the stuff passes to a stuff chest, whence it passes along sand traps over magnetic separators to remove metal and through strainers into the vat. As the quantity required by one vat is small, the straining of the stock is not forced, as it too often is for a machine, and this is a great advantage in producing clean paper. Being generally well fibrillated, the stuff is warm on leaving the beater, and it is warmed for ease and speed in making, and to save the vatman from having to slow down so as to handle cold stuff. It is also kept stirred while in the vat by an agitator or 'hog'.

Moulds for Hand-Made Paper.—The foundation of a mould for making hand-made paper is a framework of hardwood into which are set at convenient distances a number of thin transverse wooden bars, which are perforated with small sewing holes.

Used in conjunction with this frame is what is termed the deckle, which closely resembles a picture frame, and when placed in position on the mould provides the necessary edge to keep the pulp from running off the mould back into the vat. It also determines the exact size of the sheet of paper.

The surface of the mould (called the 'sheet') is provided with either a laid wire sheet or a woven wire cloth, the laid being the older form of covering. In either case it is sewn down to the framework, the sewing wire passing through the perforations in the bars.

The laid sheet is so called because its component wires are actually laid in position by hand as the cloth is formed, being held together by chain or twist wires, and the construction of this type of mould differs but slightly from the earliest types. At the present time most of these coverings are laid mechanically, with the result that the mould has a much more even surface, but there are still a good many moulds made with hand-laid 'sheets'.

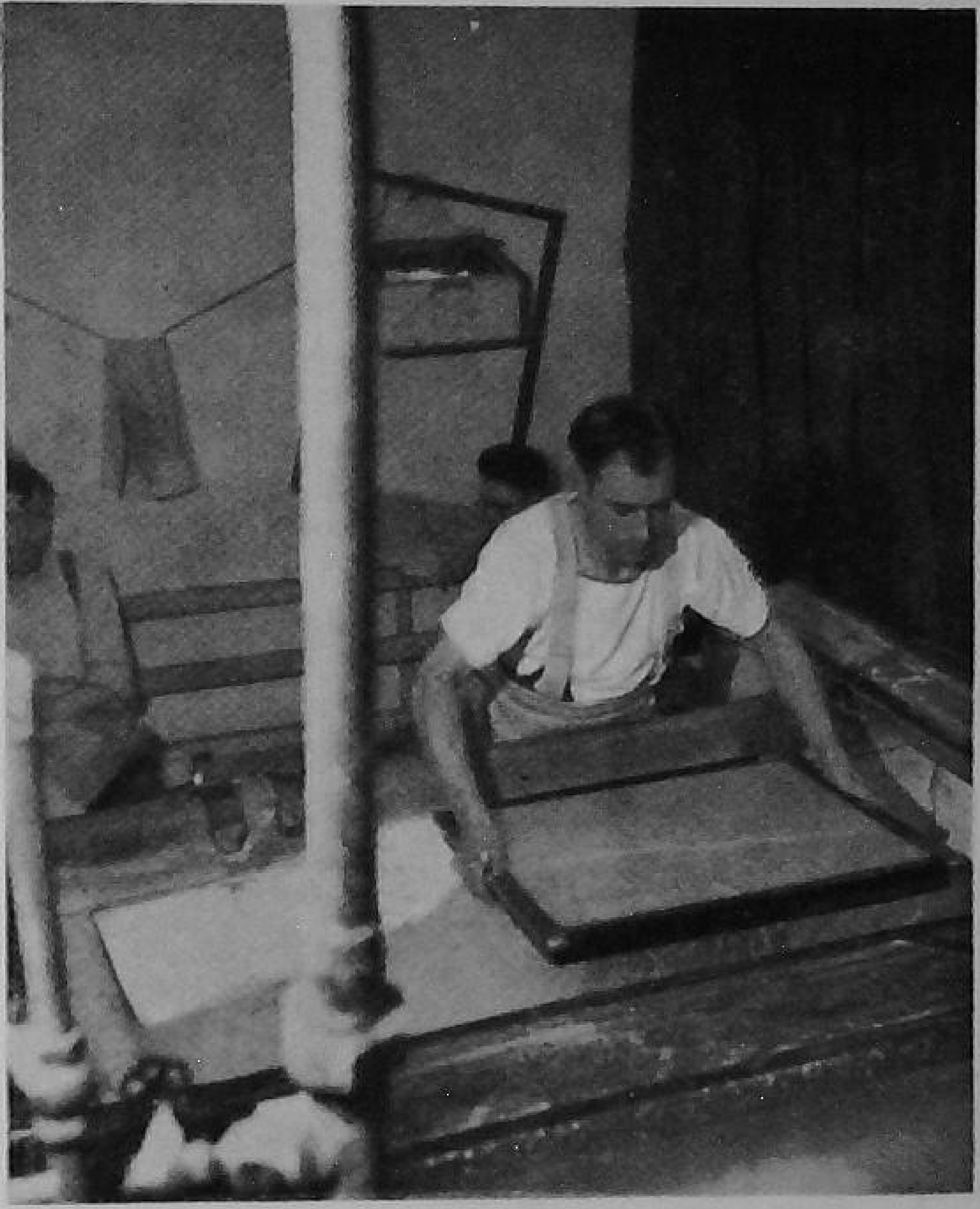
In its earliest form a paper mould was probably formed by knitting or weaving vegetable fibres or split cane together to form a sheet, and then stretching this sheet over a mould in such a way as would provide an adequate surface for the pulp to be lifted from the vat and drained.

The introduction of drawn wire largely benefited the construction of paper moulds, both in the case of laid sheets, and later in the introduction of the woven type of sheet or cover.

It may be mentioned that the earlier types of moulds have the laid sheets

placed directly on to the bars, the position of the chain lines being directly over the wooden bars, and this causes the slight shading appearance in the paper around these parts.

With the mechanically-made 'sheet' it has become customary to introduce a laid under 'sheet' which, by giving a slight clearance between the top sheet and the mould, allows for a better waterway, gives a more evenly water-marked surface to the paper and does away with the shaded appearance mentioned above.



[*J. Barcham Green Ltd.*

FIG. 206.—VATMAN MAKING A SHEET OF ROYAL. THE WAVE IS SEEN GOING OVER THE MOULD.

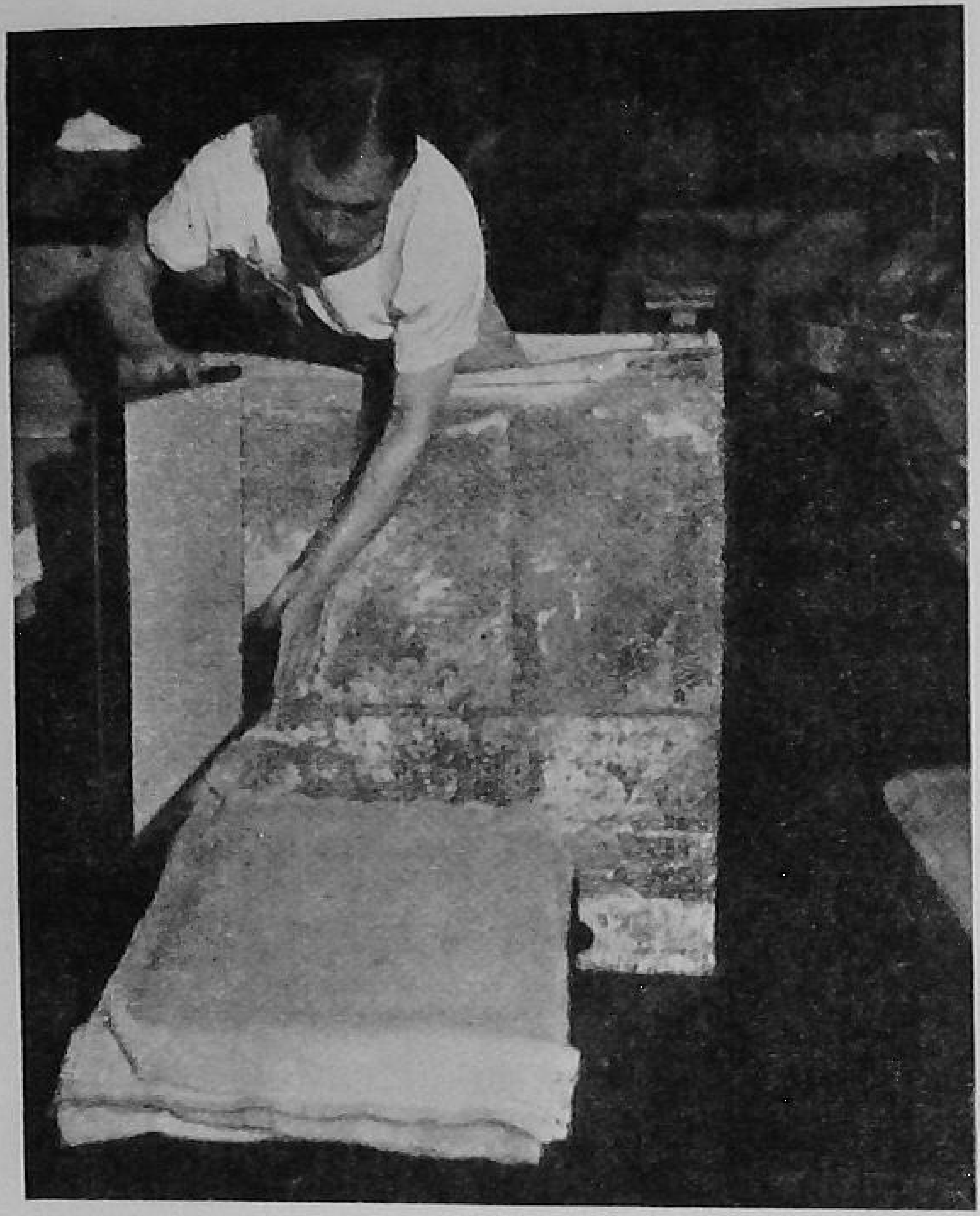
Letters or devices are sewn on the surface of the wires or wire cloth. Some moulds have patterns or figures embossed on the wove wire cloth both up and down, so as to form thick or thin places in the sheet, and many beautiful designs are produced in this way.

The paper-maker who handles the mould and makes the waterleaf sheet is called the 'vatman' (Fig. 206). With the deckle in position he dips the mould into the stuff in the vat, and, lifting it up, he gives it the peculiar shake and movement which closes up the sheet and gives it the desired character; he sometimes causes a little wave to run over the mould, so getting rid of the surplus pulp, and leaving the fibres evenly felted behind it. He tips some of the water off the top and then places the mould on the bridge beside him, within reach of the coucher, at the same time removing the deckle.

The coucher tilts it into a sloping position to allow more of the surplus water to run through the sheet and off the under side of the wire cloth, and then presses it face downwards on to a felt. Skilfully lifting the mould from one edge first, he leaves the wet sheet on the felt, and places another felt on top of it. Another sheet is laid on the pile, and so on until a 'post' of alternate sheets and felts is built up (Fig. 206a).

This post is subjected to heavy pressure in a press, to squeeze out as much

water as possible. The sheets are then stripped off the felts by a 'layer' and piled into 'packs', which are taken and pressed again for some hours (Fig. 207). These packs are then separated sheet by sheet carefully, and then they are pressed again for 12 hours, when they are again parted, pressed again and then hung up in a loft to be air-dried. In summer the natural air is enough, but in winter steam-pipes are used. When sufficiently dry the paper is stacked up in piles to mature and flatten out. This maturing process may take weeks or months. The waterleaf is now ready to be sized with gelatine.



[*J. Barcham Green Ltd.*

Fig. 206a.—Jack Coles couching. He has just let go with his left hand and is about to put the mould on the felt in order to couch the sheet.

The sizing is carried out in a sizing machine, which consists of a tub through which two endless felts travel slowly, with the sheets of waterleaf between them. After the sheets have been well soaked they are carried between squeezing rolls to force the size into the sheets and also to remove excess size from the surface of the sheets; this prevents subsequent discoloration by reason of patches of size lying on the surface.

After sizing, the sheets are stacked up in piles and covered with hot felt and allowed to stand for about 24 hours. This gives the size a chance to permeate the sheet thoroughly and the heat prevents the sheets sticking together. After this the sheets are parted by girls, so that warm air can get at them and dry off the surplus moisture.

The paper is afterwards allowed to stand in piles for a day and then again carefully parted sheet by sheet, care being taken not to strain the sheets unduly if they should be stuck together, otherwise they will be cockled and will never lie flat.

The sheets are again allowed to stand for a few hours, and are then taken to the drying lofts. These lofts are heated and care has to be taken to prevent cold air or draughts getting in, or the paper will be spoilt. Different

temperatures are used for drying different qualities of paper. The paper may be dried flat on hessian screens, or hung over cow-hair ropes. Most papers are sized a second time after drying. The stronger the paper and the more fibrillated the stock, the more difficult it is to get the paper to take the size, owing to the absence of air spaces. After drying in the loft the paper is stacked in heaps to mature, and is then sorted over for defective sheets before being plate-glazed. It is then sorted over finally by experienced sorters, who separate it into good, retree and broken.

The most important features of hand-made paper are its great strength and its tendency to expand and contract equally in both directions after damping and re-drying.

[*J. Barcham Green Ltd.*

FIG. 207.—JOE BURGESS AND JACK GARRETT PUTTING THE LAST PACK INTO THE PACK PRESS BEFORE PRESSING THE PACK TO 'NOT' SURFACE.

The shake given by the vatman is in two directions, so that there is very little difference in the tensile strength in the length and breadth of the sheet. Machine-made paper shows a decided difference in strength and expansion in the machine and cross directions.

The couching pressure is applied to hand-made paper slowly and directly at right angles, instead of the sudden rolling up of the machine couch rolls.

The expansion and contraction of hand-made paper, being much more even, are of great advantage for some special papers, such as bank-notes and other papers which have intricate designs printed on them, and which must register correctly.

Water-marking can be made very clear and distinct, and some very beautiful and elaborate designs are produced. While the dandy roll can only make an impression on the already formed sheet on the machine, the watermark on a hand-made sheet is moulded into the fabric. No loadings or resin size are used because, the paper being loft-dried, there would not be sufficient heat to fuse the resin in the sheet. Hairs from the felts were often left on the

surface of hand-made sheets, causing annoyance when a pen was used. This trouble has, however, been eliminated recently to a great extent.

The substances of sheets are sometimes very irregular before the sorting, but they are on the whole astonishingly good, when the conditions of working are taken into account. The percentage of broken is naturally higher than that of machine-made paper.

Hand-made papers are mostly sent out in rough or low finishes, especially for drawing and painting, but those for writing are usually plate-glazed. Owing to the deep impression of the felt and the absence of the smoothing process between press rolls, it is difficult to obtain a close finish.

A steel pen-nib will generally be found more satisfactory than a fountain pen for writing on hand-made paper, the surface of which usually has a 'greasy' nature, because stationers think a rough paper *looks* better, and insist on the maker supplying this, when a higher glaze would make it write perfectly well, and it really looks just as good.

It is scarcely necessary to add that the vatman and coucher must be skilled and steady workmen, the vatman in particular, for he has to make sheet after sheet without deviating from the correct substance or altering his shake.

It is also quite a common occurrence for a vatman, owing to nervous strain, to lose control of the muscles of his arms, and, as it is called, 'lose his shake', sometimes only temporarily, usually permanently.

The vatman can only do his work properly if he is in good health and 'free from care'. The least mental strain or worry shows itself at once in the resulting paper, so that the substance, appearance and character of the paper are altered or irregular. Quite frequently, when beginning to make a certain paper after having just finished making a different size or substance, it will take some time before the vatman settles down and gets the paper right, and he usually knows himself that it is wrong, and marks it with tabs so that it can be set aside for repulping or special sorting when finished.

The finished paper is finally sorted by 'layers', who are women of great experience. These layers throw out defective sheets, which are in their turn sorted again by 'second layers' into retree and broken, so that finally three grades are left—namely, good or perfect, retree and broken. These grades are all fit for sale, but the retree and broken are sold at a lower price, in the same way as machine-made papers. The reams are made up in various ways—namely:

1. *Mill reams*, containing 472 sheets (432 good, with 20 broken sheets on top and the same number of broken sheets at the bottom of the ream); this method is now given up by most mills.

2. *Insides*, 480 sheets, all 'good'.
3. For export, 500 sheets, all 'good'.
4. *Retree insides.*
5. *Retree mill reams.*
6. *Broken.*

[It is often said that hand-made papers are expensive. This idea is quite erroneous when the superlative excellence, strength and durability of the finished sheet are taken into account. Hand-made papers are actually cheaper than machine-made papers in comparison, when the conditions of manufacture are considered.]

For instance, a mill with five vats, making about 3 tons of paper per week, requires 125 employees for the various processes, and burns 25 tons of coal, 60 per cent of which is for drying, some power being obtained from the river. It takes from *two to three months* for a sheet of paper to find its way through the mill, and the various processes entail about *one hundred* separate handlings.

There are a good many purposes for which hand-made papers are essential, and for some of these they are actually a good deal cheaper in the long run than are machine-made papers.

Drawings.—The fine texture and 'tooth' characteristic of hand-made papers render them essential for the beautiful work of the real artist.

Etchings.—For printing wet or dry, the etcher wants a paper which will withstand the pressure and yet be sympathetic to the plate, combined with a lasting quality and purity that are not to be found in machine-made papers.

Money paper and all documents which get a lot of handling have to be printed on the very best paper obtainable, and the slight extra cost of hand-made makes the paper much cheaper in the long run. Very intricate lettering and devices can be put into these papers, and the English hand-made mills make money paper for banks and governments all over the world.

Mounts and Covers.—Half the battle, when one wants to display a good picture, is to have a suitable background, and there is nothing to equal a good hand-made mount, which can be obtained in white and almost any shade of colour, even to black.

Vellum Papers.—The amazingly strong imitation parchment papers made by hand are equal to and in some ways superior to real parchment. They are practically indestructible, and they are not so easily affected by heat, mildew or insects as are skin parchments.

Filter-papers for the most delicate chemical analysis are almost invariably

made by hand, and they are the most reliable, the amount of ash in some of the chemically treated 'ashless' papers being practically nil.

Notepapers and Envelopes.—There is something distinguished-looking and 'good' about hand-made notepaper which cannot be imitated by any of the machine-made varieties. A box of good hand-made paper is actually much cheaper than many of the gaudy cabinets and compendiums of inferior engine-sized notepapers which are to be seen in all stationers' shops, and which seem to have a ready sale.

Ledger Papers.—For ledgers and account books, which have to be durable and stand a lot of hard usage and fingering, there is nothing to equal the blue-laid English hand-made papers.

Printing Papers.—For costly editions of valuable books, and for *éditions de luxe*, hand-made printings are still in good demand, and they give an added charm to the volume when combined with good and tasteful printing.

A maker of hand-made paper is a craftsman who has served at least seven years of apprenticeship before he gets his 'Card of Freedom', and until he obtains this card, which may only be awarded him by the Society, he is not allowed to be employed in the making of hand-made paper. The result is that after many years of tuition there exists a body of workmen called 'The Original Society', who are highly trained and who enjoy a freedom not possessed by any other organization of workmen.

It is interesting in this connexion to note that membership of the Society can be traced from generation to generation, son following father in unbroken succession, and several of the fifth generation are employed in the hand-made mills to-day. The same holds good of the employers also.

[We are indebted for much of the above information, and also for the blocks of the illustrations, to Messrs. J. Barcham Green, hand-made paper-makers, Hayle Mill, Maidstone.]

CHAPTER XXIII

GELATINE-SIZING — HAND-SIZING — TUB-SIZING — AIR-DRYING

The best writing and typewriting papers, whether machine-made or hand-made, are always 'sized', or coated and impregnated with a solution of gelatine, in order that their surface may be more even and more resistant to ink.

Papers sized with a gelatine solution are freer from fluff and 'hairs' on the surface, as these are all glued down among the other fibres and do not become attached to the pen-nib.

In the case of a gelatine-sized paper, the ink lies on the thin film of gelatine and dries there, so that it may, if necessary, be erased and other letters or figures substituted.

Papers are sometimes required to 'stand ink after erasure', which means that they must be hard 'engine-sized' before they are tub-sized. In this case, when the paper has been hard-sized in the beater, less gelatine is taken up in the same time, as it does not penetrate the sheet to such an extent, but lies on the surface. The writing is easily erased, the gelatine being removed with it, and more writing may be filled in without the ink 'running' to any great extent.

Gelatine-sized papers are much more durable, as the fibres are protected by the thin film from the oxidizing agents of the atmosphere. They are also rendered more tough and will stand folding and rough handling. The gelatine also imparts other distinctive qualities to papers, such as 'snappiness', handle, feel and look-through.

Hand-Sizing.—All hand-made and, in some cases, machine-made papers are sized in sheets, and the method is called hand-sizing, as it was originally carried out by dipping sheets of waterleaf into a tub of gelatine.

The sizing is now done by placing the sheets between two endless travelling felts, which run through a bath of warm gelatine size. The sheets are carried into the size and thoroughly soaked in it, the felts, which are very thin, having holes punched in them to allow the free passage of the gelatine. The excess size is squeezed off by means of a pair of press rolls, through which the felts carry the sheets; the latter are then taken off and stacked ready to be taken to the drying loft, where they are dried by air at various temperatures. The sheets may be hung by clips or laid on hessian, in which case

they will be dried flat, or they may be hung over cow-hair ropes and dried with a 'back' or ridge down the centre, caused by the rope; such papers are called 'backed' and the ridge has to be cut out by means of a guillotine, the 'deckle edge' thus being absent on one side of each half of the original sheet.

Tub-Sizing.—In the 'tub-sizing' of machine-made papers in a continuous web the paper is run off a reel, or straight from the drying cylinders, through a tub of gelatine size and again reeled up to 'soak' or run straight over an air-dryer, which will be explained in detail in a subsequent paragraph.

Preparation of Gelatine Size.—Most mills do not now prepare their own size, but find it more economical and clean to buy the particular grade of gelatine which is best suited to their need, ready prepared in sheet form.

This method does away with the necessity of buying skins and wet pieces from tanyards, boiling them down and running off several 'draws' to make the sizing solution.

For those who wish to make their own size the following details may be of interest:

The wet hide pieces are soaked in cold water and washed in revolving drums to free them from the lime which has been used to preserve them.

The size is extracted from the skins by boiling them in copper-lined, jacketed heaters, into the bottom of which is fitted a wooden frame covered with openly woven cloth. The solution of size passes through this sieve and the slime and other objectionable matters are kept back.

The heat is brought up to about 170° F. and the charge stands for about 16 hours before being drawn off. The heat must be put on again before drawing off, in order that the first draw may run off easily to the store tanks.

The first 'draw' contains the strongest jelly, but one or two more 'draws' are made in order to extract the whole of the gelatine. The second heating, with a fresh supply of water, is conducted at a temperature of about 190° F., and is allowed to stand as in the first treatment.

A third and fourth infusion may be made, the third being heated up to about 200° F., and the fourth boiled for an hour or two.

The amount of water added to the heaters for each treatment must be regulated according to the strength of the size required, and will, of course, depend upon the quality of the skins. The size should be strained through flannel cloth over a wire sieve.

The strength of the size for the store tank is regulated according to requirements by mixing together various amounts of the different infusions, such as the first and fourth, second and third, or any other which may be found suitable.

For the reason that size of different strengths may be easily obtained in this way, some mills still continue to make their own. By using a bath of size made entirely or almost entirely from the first draw, a very hard-sized paper is obtained, and one the strength of which is very greatly increased; for other papers, weaker solutions will suffice.

A small percentage of white soap is added to the size and thoroughly mixed up before adding the alum; about 2½ per cent is the usual amount. If the soap is not put in before the alum the size will curdle. The soap must be pure tallow curd, and may be bought, specially made, under the name of 'paper-makers soap'. The soap helps to give a high finish to the paper, and it also prevents the formation of glistening alum specks on the surface of the paper.

Alum is added in the proportion of about 14 or 16 lb. to 112 lb. of gelatine, reckoned on the dry weight. The function of the alum is threefold: it serves to stabilize the consistency of the sizing solution at various strengths and temperatures, and also acts as a preservative by arresting the formation and growth of destructive bacteria, which quickly destroy the gelatine and cause it to putrefy; the third function of the alum is to render the gelatine resistant to ink penetration.

The effect of the alum on gelatine solution is very curious. If it is slowly added, it causes the gelatine to thicken until it becomes almost solid; when, however, more alum is added, the gelatine becomes fluid again, and it is in this condition that it is used in the size-bath. About 12 or 14 per cent of alum will be required to produce this solution. The normal way of testing the density of the solution in the mill is by means of a special hydrometer which has two scales of figures.

For a good quality paper in substance about 16½ × 21, 21 lb., 480's, the temperature of the bath should be 110° F., and the density 7, as shown on the hydrometer. This figure is arrived at by allowing for the temperature on the scale.

Only the best sulphate of alumina must be used, and it must contain no iron or free acid.

Excellent gelatine may now be obtained in the form of small sheets ready for dissolving, and this saves the paper-maker the lengthy and rather unpleasant business of preparing the size from skins.

These skin and bone glues are made in a wide variety of qualities and colour, from dark brown to almost colourless (bleached). In order to find a grade suitable for tub-sizing, various samples may be tested. The qualities most desired are penetration at high temperatures and good stiff gelatinization at ordinary atmospheric temperatures.

This simply means that the solution should penetrate the surface of the paper while it is passing through the tub, and then dry hard on the dryer afterwards, giving the maximum resistance to ink and moisture and the maximum increase in strength and bursting strain. When testing gelatines, the colour of the solution must be taken into account, because the use of dark-coloured solutions will bring down the colour of the paper to an appreciable extent.

A rough way of testing samples against each other is to weigh out pieces according to their price; soak in water for 24 hours, remove them and wipe off surplus moisture, and then dissolve in equal quantities of water in a water-bath. When all the jelly has dissolved, remove the dish from the water-bath and allow to stand until cold. The stiffest jelly will be the most economical, and, if its colour is satisfactory, will be the best for tub-sizing.

The stock solution of size is made in the following way: the sheets are placed in a tank, covered with cold water and allowed to stand for 24 hours. By this time they will have swollen to several times their original thickness, but they will not have dissolved. The water may be drained off and hot water added, or the temperature of the water in the tank may be raised to about 150° F. The jelly will dissolve, and soap may be added in the proportion of about 2 or 3 per cent on the dry weight of gelatine. When the soap has dissolved, 12 to 14 per cent of alum is added, and the size is now ready to be run to the store tanks. Here it is tested for strength, and if too strong it is diluted with hot water to the required strength. It is now ready for use.

The tub-sizing machine consists of a trough, either of wood, lined with lead or copper, or of cast iron with a copper lining. No iron- or steel-work must come in contact with the gelatine solution.

The trough is heated by a copper steam coil or may have a double bottom with hot water circulating across the under side, in order that the temperature of the size may be kept constant. The best method is undoubtedly that in which hot water circulates through the bottom of the entire tub, as in this way the whole of the solution is kept at a uniform temperature. The temperature of the size is indicated by a thermometer kept permanently in the tub. A thermostatic controller will give perfect results.

Various methods are used for leading the web of paper through the tub, and all paper-makers seem to have their own ideas about it. The main principles to be borne in mind, however, are that the paper should be soaked for a period sufficient to allow it to expand to the utmost, otherwise trouble will be experienced with ribbing or piping of the paper as it is wound up wet after leaving the tub. This ribbing is caused by the paper still taking in size and expanding while being tightly wound, and as it cannot expand

easily outwards, it expands upwards and takes on a shape resembling that of corrugated iron.

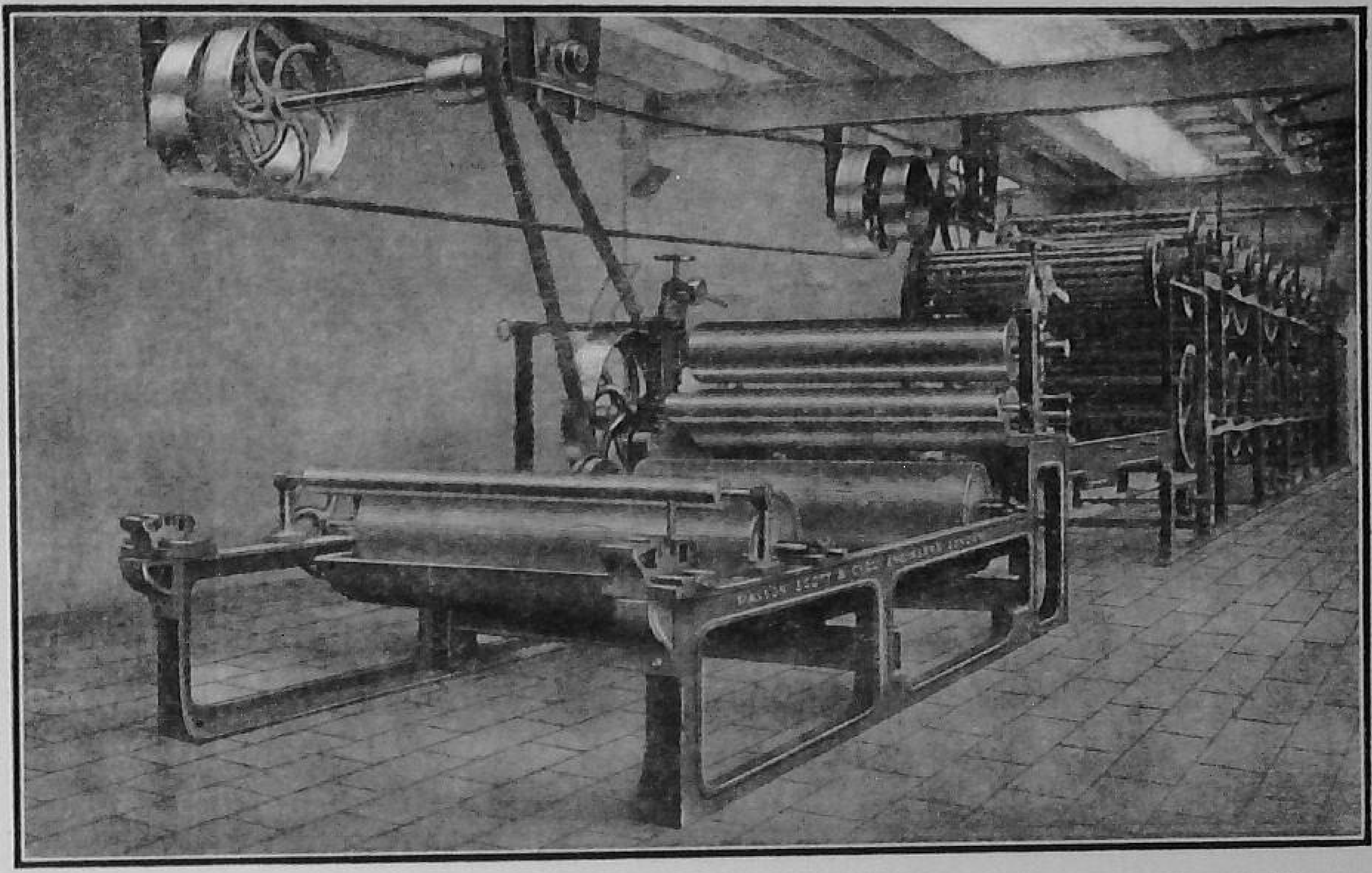


FIG. 208.—TUB-SIZING AND AIR-DRYING PLANT, SHOWING TUB AND SQUEEZE ROLLS; ALSO SPARRED DRUMS OF DRYER

A suitable arrangement of squeezing rolls must be fixed at the end of the tub in order that the excess size may be removed from the surface of the paper before it passes to the air-dryer, or is wound up.

A satisfactory arrangement of tub-sizing plant is illustrated in Fig. 208. The paper is led, either direct from the steam-drying cylinders of the machine or from a reel, over a dancing roll and round a large wooden roll fixed in the front of the tub. This roll is half submerged in the size, and the web of paper passes under it and along the bottom of the tub to another large wooden roll, also half submerged in the size. The web is led round this roll, and out of the size, over a guide roll, and into the nip of the squeezing rolls.

The squeezing rolls are important, and various combinations are in use. They may be either brass on brass, rubber and brass, or granite and rubber, the latter making an excellent combination. These rolls, no matter of what they are made, must always be kept in good condition, free from ridges and blemishes of any kind, and they must fit evenly the whole way across, otherwise damp patches will occur in the paper, and these will show in the finished sheet. Rubber rolls must be most carefully handled, as they are easily scratched and damaged, and the least mark in the roll will leave a

corresponding mark on the paper, which may be visible only in certain lights.

The rolls must always be kept clean, and the top roll should be provided with a doctor and spray of water in order to wash off any froth or scum, and should be fitted with levers and weights, so that the pressure may be regulated.

Mention has already been made of the thermometer which is fitted in the tub; this should be in such a position that it may be easily seen all the time, as endless trouble may be caused by the temperature falling below its proper height.

During the working of the tub a great deal of froth is formed by the agitation of the size; this must be removed regularly in order to prevent it becoming hard and getting on to the web, and being pressed in by the squeezing rolls, thus causing hard size lumps or spots in the finished paper.

The level of the size in the tub should always be carefully regulated, as trouble is often caused by the level being allowed to get too low, and the scum which floats on top settling on the web, causing blemishes in the finished sheet.

The best sizing results are obtained when the paper enters the tub in air-dry condition, is absolutely flat and free from cockles, creases and wrinkles of all kinds. It will be found advantageous to pass the paper over a scraper before it goes into the tub, in order to remove loose particles of rubber, which often adhere to the surface and stand out prominently after passing over the drying cylinders.

Opinions differ as to whether the paper should be reeled up after sizing and allowed to stand and soak for a time before being dried. It is the practice in some mills to have several reels lying sized for some hours before drying, while others allow the reel to soak while the previous one is being dried; others, again, run the paper straight from the tub over the dryer.

So far as the efficiency of the sizing is concerned, there seems to be little to choose between the various methods, and our experience leads us to the conclusion that the latter method—namely, running the paper straight through the tub and over the dryer—is the most economical and convenient, although it means that the sizing and drying must always be done at the same speed. Nevertheless, by this method we have sized papers in the same tub varying in substance from Large Post 7 lb. to Large Post 35 lb., with excellent results.

The second method seems a waste of time, as that part of the paper which has just left the tub is the first to pass over the dryer, and consequently one

end of the paper will have been soaked for an hour or more while the other will be fresh from the tub.

The prolonged soaking of coloured papers is not advisable, as the colours are liable to fade.

Another drawback with reels which are allowed to stand and soak is the fact that the deckle edges often stick together and cause tears at the edges of the paper when being unwound at the dryer. To prevent this, the sides of the reel must be washed with hot water, or a jet of steam should blow gently against them during the unwinding.

The only point in favour of sizing and drying in two separate operations is that the speed in the 'straight-through' method cannot be varied to suit varying conditions of the atmosphere, and the slower the drying has to be done the longer the soaking of the paper in the tub.

When the two operations are separate, the dryer can be slowed or quickened at will, as the dryness of the paper demands, without interfering with the sizing.

Tub-Sizing with Feculose.—Feculose is sometimes used for tub-sizing writing papers, either in combination with resin or with gelatine size. Provided that the paper has not to be free from starch, excellent results may be obtained so far as hardness and resistance to ink are concerned, if resin is also used, and feculose is usually cheaper than the better grades of gelatine.

The method of preparing the solution is as follows:

200 lb. of feculose are stirred up with 90 gallons of water, warm, but not above 160° F., and heated with steam injection until the temperature reaches 205° F. Allow to stand ½ hour to ensure thorough cooking, then add 800 lb. (80 gallons) of cold water.

10 lb. of resin size are placed in a tub and 8 gallons of water added, then heated to dissolve the resin size with the addition of ½ lb. of soda ash (the resin size is used just as it is delivered); then add 5 gallons of feculose solution.

10 lb. of alum are dissolved in 8 gallons of water with steam injection and 5 gallons of feculose solution are added.

The made-up resin size should now be added to the feculose solution through a sieve and mixed well with a wooden paddle; next add the alum solution and stir.

The feculose solution is now ready and should be about 8° to 9° Tw., but can be diluted to any desired strength.

By following this method the colloidal condition of the resin is obtained, and therefore its maximum efficiency assured.

If the paper has been well sized in the beater, the resin and alum can be

cut out, but it is advisable to add ½ to 1 per cent of formalin calculated on dry feculose to ensure the keeping qualities of the feculose solution. Where alum is used the formalin is not required, as the alum prevents fermentation. Formalin does not thicken feculose as it does glue.

With pure rag paper, where the resin does not exceed ½ per cent, the quantity of resin added to the feculose solution should be doubled.

The sizing may be carried out in the ordinary size-tub of a tub-sizing machine and the paper then dried by hot air. As an alternative, however, a bath of feculose of about 10 per cent strength may be placed after the presses, and immediately before the steam-drying cylinders of the machine. In order to give full ink resistance, resin size is added to the feculose in the bath and precipitated in the usual way by alum. The heat of the drying cylinders does not affect the feculose size adversely, as is the case with gelatine.

Paper sized in this way should not be called 'tub-sized', as this term has long been applied to high-grade papers sized with gelatine, and it is likely to be misleading.

Air-Drying.—To carry out this operation the paper is led over a series of sparred drums about 3 feet in diameter, by means of cotton tapes. The drums are composed of iron ends and spindle and have wooden spars. Some of them are also fitted with metal fans revolving in the opposite direction, in order to agitate the air and keep it in motion, and these fans also assist in keeping the paper flat and preventing it from running into creases. They are generally arranged in tiers.

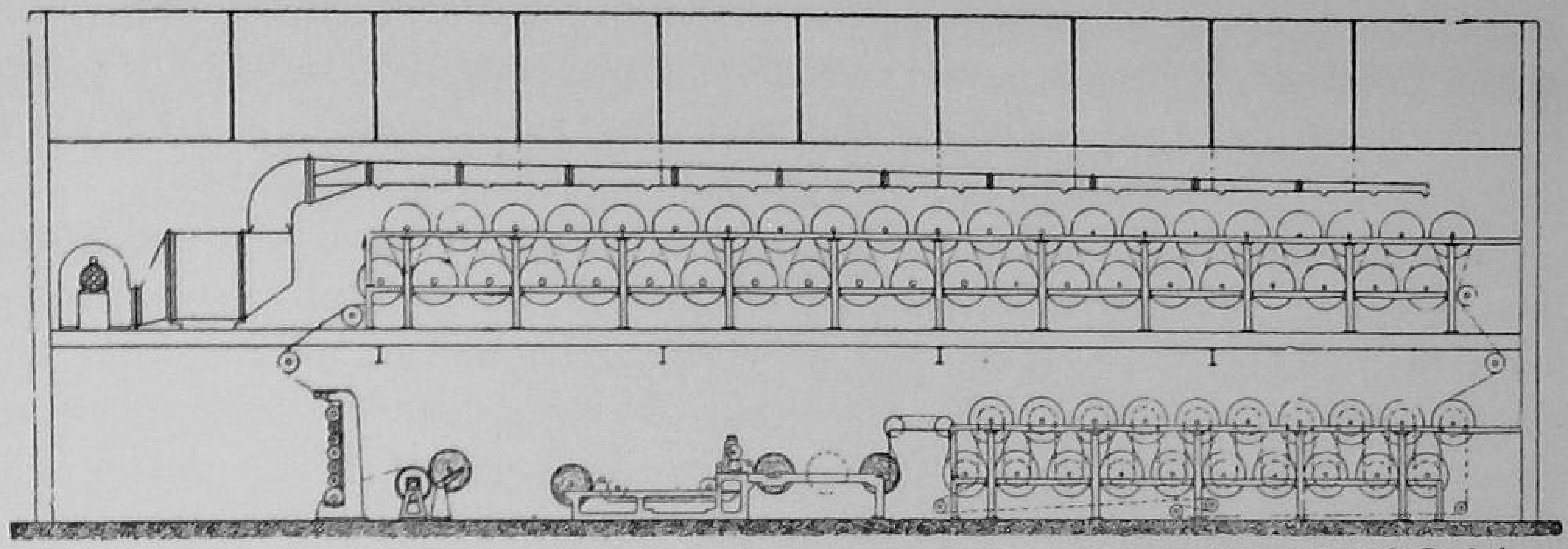
Attempts have been made to dry a tub-sized paper in an enclosed dryer where hot air can be circulated, and thus dry the paper quickly and in a much smaller space than is required with the ordinary sparred drums in a heated room. So far as we are aware, this method has been found quite successful.

A typical air-dryer is illustrated in section in Figs. 209 and 210. If the paper has to be dried at a high speed a very large number of drums is required, as many as 120 or even 140 being used on some machines.

The arrangement for supplying hot air consists of a series of steam pipes running along the floor under the dryer, and the heat of the room is regulated by a valve worked in conjunction with a steam pressure gauge and a thermometer, or by a thermostat.

Some of the latest dryers also have a hot-air blower arranged to supply extra warm air to the upper tiers of the dryer, as it was found that by the time the air had risen from the first and second tiers it was so charged with moisture as to be unable to remove the final traces from the third tier.

There are several different forms of procedure adopted by various mills. In some cases the dryer is situated at the end of the machine immediately



[Masson Scott & Co. Ltd.

FIG. 209.—SECTION OF TUB-SIZING AND AIR-DRYING MACHINE, SHOWING HOT-AIR BLOWER ON TOP SECTION
The dried web is brought back to the bottom floor to be calendered.

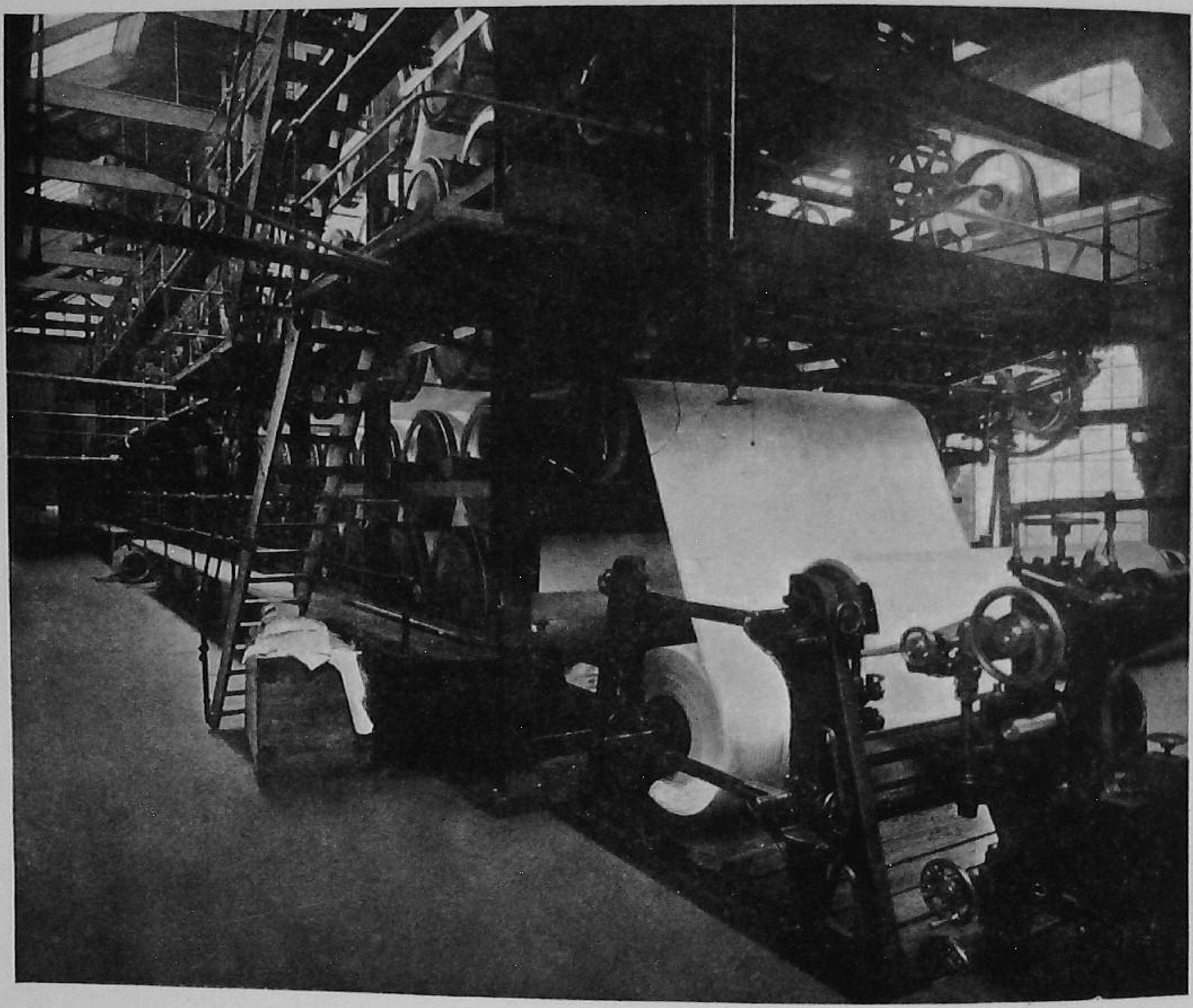
following the size-tub, so that the paper may be run straight from the drying cylinders, through the size-tub and on to the dryer, in a continuous web. This is the cheapest and best method, from the point of view of labour saving and the reduction of broke. Obviously, if the whole operation of making, sizing and drying is carried out in one room, not more than five men and boys will be required, and when the machine has to stop to wash up or change, all five men will be available to assist at the wet end in cleaning sand traps, strainers, washing felts, etc., and so the length of time taken for this very necessary work can be reduced to about one-half of that which would be taken by a machineman and one assistant, were the machine separate from the dryer.

Another advantage of this method is that a sized and finished sample of the paper can be got in the shortest possible time for the purpose of comparing it with the sample to be matched. The sizing always affects the colour of the paper in some degree, and if a waterleaf sheet only is available for comparison with a finished sheet, allowance will have to be made for the colour 'going back' a little after sizing.

Among the disadvantages which might be claimed against this method may be mentioned the fact that sizing and drying have to be done at the same speed at which the paper is being made, but we know of two very satisfactory machines on which this method is used, and the speed of the machine has never been affected by sizing or drying troubles. Of course, a sufficiently large tub and a long or hot enough dryer must be provided to size and dry the paper at the maximum speed of the machine.

A slight variation of this method is to have the machine, size-tub and

dryer arranged to follow straight through, but to reel the paper after sizing and then pass it over the dryer. It is, however, difficult to see what advantage



[*Wiggins, Teape & Co. Ltd.*

Fig. 210.—Air Dryer of a Large Tub-Sized Machine

there can be in this, except that the size gets a little time to soak in, for the *last* part of the reel to be sized is the *first* part to be dried, and supposing that the dryer is run one reel behind the machine, some of the paper will be dried almost immediately, while some of it will have been soaking for an hour or more. Surely this must result in *unequal* sizing, if it is claimed that better sizing is obtained by allowing the paper to soak in the size.

We are of the opinion that in actual practice the difference is negligible between sizing results from soaking and drying straight away. In some mills the making, sizing and drying are carried out in three separate operations, the sizer and dryer being right away from the machine. This method means that the paper has to be wound up three times and unwound twice, and at

each of these operations some paper is spoilt. It also means more labour, as it is impossible to shut down a sizer or dryer to send men to help wash up the machine, etc. The only advantage which can be claimed for this method is that the speed of each machine can be adjusted to the exact requirements of the paper, and if trouble is being experienced at the size-tub, the machine need not be stopped. The same applies to the dryer.

Another arrangement is to reel the paper at the end of the making machine and then to size and dry it in one operation. This method is the best and usually the most convenient, if it is impossible to arrange all three operations simultaneously. The output of the machine cannot be affected in any way, and it will usually be found possible to make up any lost reels when the machine is shut for changing, etc.

The web of sized paper is led over the sparred dryers by means of tapes until it reaches the calenders and is started on the reel. The tapes may then be run off the paper to the side of the drums, in order to avoid marking the paper and causing cockling. It is, however, sometimes necessary to keep at least two tapes on the paper, one above and one below, to keep the web tight and prevent it running off to the side of the drums. It will be an advantage if the spars of the first twelve drums are covered with strips of zinc or copper, as a certain amount of size is always deposited on the spars of the first few drums, and must be scraped off periodically. It is not easy to scrape wooden spars without damaging them, but zinc- or copper-covered spars are easily cleaned with a cloth and hot water.

Trouble is sometimes experienced from paper cockling or creasing at the dryer, owing to the fact that it has not completely expanded in taking up size in the tub. The root cause of this trouble is that the paper is not long enough in the tub, but it can be got over by allowing the web to pass along a travelling felt between the tub and the dryer, in order that it may have sufficient time to expand fully before it is tightened up on the drums of the dryer. An old wet felt can be utilized for this, and will last a long time, but it must be washed at least once a week.

In the drying of thin banks cockling and creasing can sometimes be traced to the fan speed, and this should be capable of easy adjustment. The speed of the fans is often excessive. If the air is kept in constant agitation and prevented from lying stagnant inside the drums, nothing more is required.

The temperature of the drying room is important, and should be kept at about 85° F. and as dry as possible. Drying is much easier in the summer than in winter, and on a dry day than on a wet and foggy one, unless, of course, specially heated and dried air only is allowed to enter the room, and

adequate fans are provided for the complete removal of all air after it has become charged with moisture from the paper.

Very large dryers are usually divided into two or three sections, and these should all be separately driven and have cone pulleys for easy adjustment of the draws. The drums themselves should be driven by endless cotton belts running on the ends, in preference to gears, as the draws and tension are much easier, and any slight variation in the size of the drums, due to wearing away of the wooden spars, has less effect in causing uneven tension between drums. Endless trouble from creasing, especially on thin weights, will always result from unequal draws between drums, if gears are used, and especially if there are too many drums in one section.

It is often an advantage to have three steam-heated iron drying cylinders at the end of the dryer in order thoroughly to dry the paper after it leaves the sparred drums. These cylinders should have woollen felts, and it will be found that they also assist greatly in flattening the paper before it passes to the calenders, besides enabling thick papers to be thoroughly dry. The heat must not be too great, or the gelatine will be made too brittle, and the strength of the paper will be greatly reduced.

A departure from the usual practice was recently adopted on a machine having 120 drums. These drums were arranged in three tiers, but it was found that the paper was often very flabby, due to imperfect ventilation of the room in wet weather, and also the large number of drums required considerable power to drive. Consequently, the bottom tier, which consisted of eighteen 3-feet drums, was fitted with steam-pipes inside and about 3 inches away from the paper. These pipes were led back and forwards across each drum twelve times, in exactly the same way as are the steam-pipes under the hood of some M.G. machine cylinders. The pipes were divided into three sections, one for each six drums, in order that the heat could be regulated for each section.

When this arrangement was in operation it was found possible to do away with 100 drums altogether, and to get a better dried and harder handling paper with only eighteen drums, and two extra drums with fans but without steam-pipes immediately after the tub. This is, of course, a method that is applicable only to the cheaper grades of tub-sized papers. Theoretically, the best results should be obtained with air at a low temperature and low humidity, but the practical application of this theory is not commercially possible. A very long drying machine running very slowly would be required, and the high moisture content of our air during a great part of the

year would render drying almost impossible. Drying machines are therefore as nearly adapted to the general quality of paper made in the mill in which they are installed as experience shows to be approximately correct.

Apparatus for controlling the temperature and humidity of rooms is now available, but is still troublesome and requires a good deal of attention.

CHAPTER XXIV

DAMPING — SUPER-CALENDER — PLATE-GLAZING — CONDITIONING — CUTTING — GUILLOTINE — SLITTING AND WINDING — SORTING AND FINISHING

Damping.—The damping of paper is the first step to the finish or surface given by the super-calender. There is little necessity for damping paper that is machine finished, the necessary condition of moisture being obtained by judicious drying. Dryers for tub-sized papers are often fitted with two or three sets of finishing rolls, and the paper is dried soft enough to take a good finish. But where a higher and finer finish is required, it is necessary to damp the paper to reduce the harshness of the fibres and soften them sufficiently, so that the heat and pressure of the calender rolls can smooth and glaze the surface of the sheet. A paper intended for super-calender finish is usually run through a few nips of the rolls at the paper-machine, and is damped before it runs on the reel.

One of the simplest and most efficient dampers is the brush damper. This is a roll brush with hard bristles which dip into a shallow trough of water. As the roll revolves, the bristles carry round a certain quantity of water. This is flicked off by the bristles coming in contact with a doctor blade. The depth of the water and the speed of the roll are varied to get the required amount of water on to the paper.

Another type is worked by means of air jets partly immersed in water and blowing it on the web. This is very difficult to regulate, as microscopic differences in the orifices of the air jets, and their immersion in the water, make it necessary for each jet to be separately controlled, and the results of adjustments are not fully known until the paper is being super-calendered. Direct sprays have the same disadvantage.

Filtered water is necessary and a high pressure, but under the best conditions a small particle of any foreign substance may stop a spray or reduce its volume, causing streaky and irregular finish.

Jets of water impinging on a glass or metal plate, so as to rebound in the form of spray, form a very good damping arrangement, give good results and little trouble.

A type of damper which is now falling into disuse is in the form of a brass or copper cylinder cooled by an internal flow of water. Steam jets are made to play on the outside surface, and the condensed steam in a fine film

is transferred to the paper. This form of damper does not give much variation in volume of applied water, and is expensive owing to the use of steam. A felt-covered roll, partly immersed in water, is sometimes used to wet a damping cylinder.

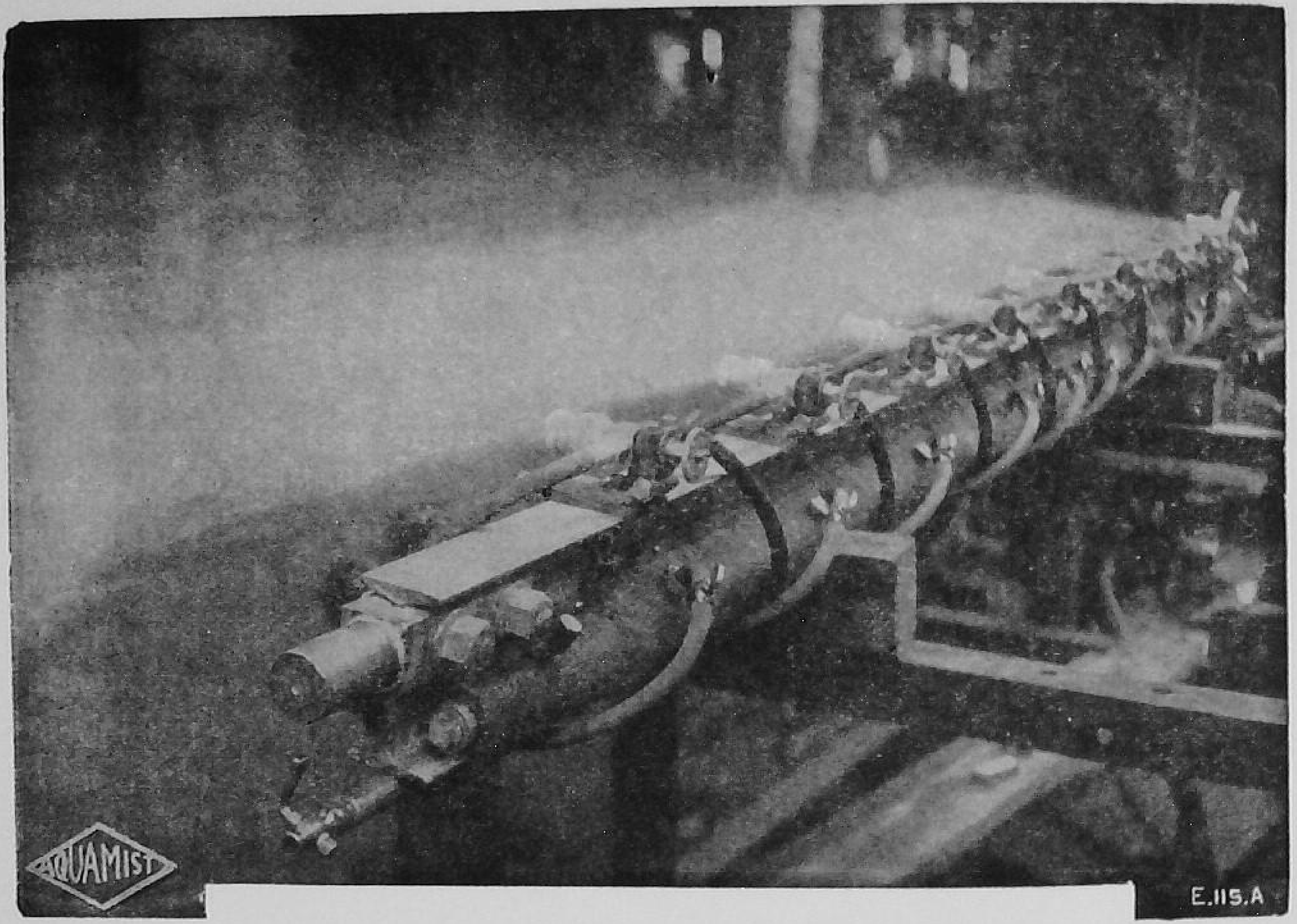
Milne's patent damper consists of a short travelling wire cloth, which is made to carry a certain amount of water in its meshes. Air jets blow this water on to the paper. Any mesh wire may be used as required for the fineness of the spray, and the speed and mesh control the quantity applied. As only the amount of water carried can be blown on the paper, the damping is very uniform and regular. The cheaper grades of paper are damped on the making machine. Better grades are damped and rewound. All paper should stand for at least 24 hours before being finished, so that the moisture will spread through the substance of the sheet and reduce inequalities of damping.

It seems to be a very general idea that best results are obtained by having the paper cool before it is damped. This entails more expense and labour in the use of a damper separate from the machine, but very few mills work this method. The usual practice for super-calendered papers is to damp the web as it is reeled on the making machine, while still in a very hot condition. Quite satisfactory results are obtained. As the damping, or application of water, takes place immediately before the paper is reeled, very little evaporation can take place in the short space of time before the sheet is covered by another layer of warm and watered paper. As warm water is more penetrative and diffusive than cold, it is only reasonable to expect that it will more readily force its way into the fibres and produce more uniform damping when the paper cools. There is no doubt that the results of practical experience go to prove that the most satisfactory damping is that carried out when the paper is hot off the machine.

Dampers on the paper-machine are already illustrated in Chapter XVII, Figs. 156 and 157. The Watford 'Aquamist' Spray Damper, Fig. 211, gives excellent results, and is easily controlled as to the amount of damping required.

The super-calender (Fig. 211a) is a stack of rolls usually eight in number, but now being built with as many as sixteen. These are alternately of iron and composition. The latter are built of discs of paper, made from cotton or woollen fabrics and cotton rags and hemp. The laminations or discs of paper are fitted on a heavy steel centre and compressed into a solid form. The roll is then turned and buffed to the correct camber. The iron and paper rolls are placed alternately, commencing with top and bottom rolls of iron.

This brings two paper rolls together in the centre of the stack. The reason for the use of iron and paper rolls is that the latter form what may be termed a



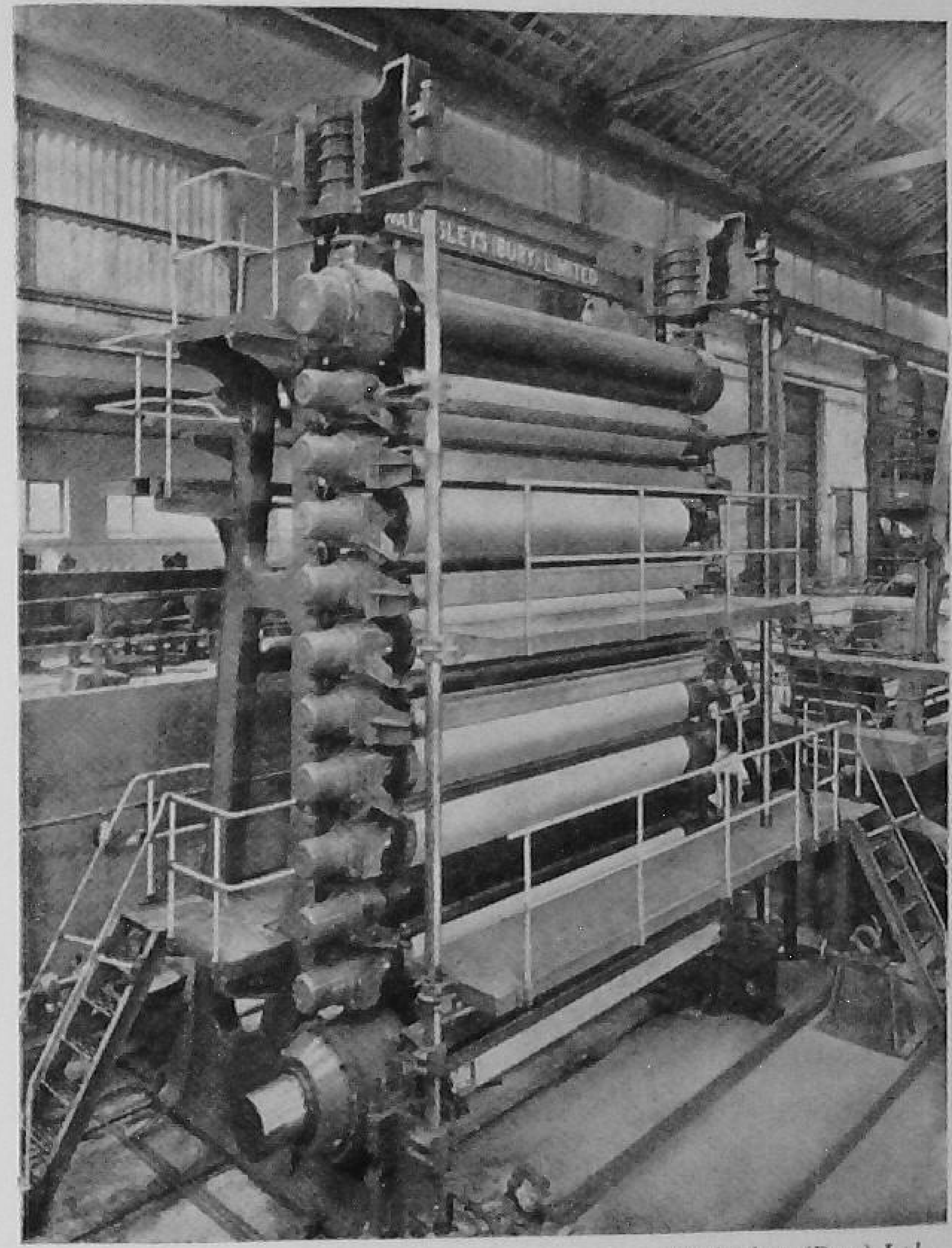
[*Watford Engineering Works Ltd.*

FIG. 211.—WATFORD 'AQUAMIST' SPRAY DAMPER ON REST, SHOWING FINE MIST-LIKE SPRAY

cushion, allowing the heated iron rolls to impart a high glaze to the paper, without the blackening or crushing and reduction of bulk which take place between two rigid iron rolls. The two adjacent paper rolls bring the reverse side of the web into contact with the iron rolls for the second half of its passage, thus giving an equal finish both sides.

The iron rolls are highly burnished and fitted for steam heating. The bottom roll is made greater in diameter than the other rolls, in order to sustain the weight of those above it. The other iron rolls are less in diameter than the paper rolls. As all rolls 'give' under pressure, the calender rolls require to be very carefully cambered. The weight of the rolls of an eight-roll calender resting on the bottom one would be about 9 tons for a 90-inch machine and about 30 tons with weights full on. This size would take 25 to 50 h.p. at 350 feet per minute, according to the degree of finish and the quality and substance of the paper being treated. The drive is either from the bottom roll or the third from the bottom. In machines with sixteen

rolls or more, the seventh from the bottom is the driver, top and bottom rolls being assisted with belt drive, to reduce slip or skid which is very destructive



[*Walmsleys (Bury) Ltd.*

Fig. 211a.—Super-Calender for Printing Papers

to the strength and bulk of the paper. When not in use the rolls should be relieved of the lever weights and lifted apart, so as to prevent the line of pressure producing a flat place.

The newer type of calenders have a lifting device for that purpose. They must be washed frequently with warm water and soap, or a little soda, to clean the paper rolls from dust, grit and resin or gelatine size. Care must be taken not to use too much heat in the iron rolls while this is being done, otherwise they will take the top skin off the paper rolls. The latter being of a softer nature, any hard substance or wrinkle in the paper is liable to make a bruise or an impression on their surface. For this reason, extra precautions are necessary when working on tub-sized papers; any defect on the deckle edge should be marked with a ticket at the drying machine and damper, and

watched for at the calender, as a folded, wrinkled or doubled corner will make a mark in the paper rolls. Hard knots of rag fibre, 'rolls' from the machine apron and ragged deckle edges are to be avoided.

In cheaper papers, the greatest danger lies in particles of metal or grit which become embedded in the rolls and may pass from one roll to another, making so many impressions that the marks become continuous all round the rolls. This is the case when there are no doctor blades on the iron rolls. Many calenders have none except on the bottom roll. A long run on a narrow width web is bad for the paper rolls, as it upsets the camber, the pressure being heaviest on the width covered by the paper. After such a run, the rolls should be cleaned and run as long as possible with frequent applications of hot water and with no weight on. This will cause the compressed part to swell out to its normal size. Bruises and imprints, if not too deep, may be cured by blowing a steam jet on the damaged place or by applying cloths saturated with hot water. Any deep cut or mark may be improved by a judicious touch up with very fine emery or glass paper and afterwards washing it with hot water. This is a temporary repair and only lessens the mark made on the paper, the proper remedy being to have the roll rebuffed. This is necessary in any case at longer or shorter periods, according to the hardness of the rolls and the conditions they show after a certain time.

As an additional damping arrangement, it has been found of great assistance to pass the paper through a cloud of steam and over a felt-covered roll before it enters the first roll. Great heat and pressure give a high but not a permanent glaze; therefore, for good class papers, it is better to put the paper twice through the rolls with less heat and weight. When finishing tinted papers, pressure and heat should be kept very regular from reel to reel, as a great many 'shades' may be caused by varying finish.

The mottled appearance of some papers is caused by bad damping—that is, insufficient time for penetration and spread of the water, or the damper throwing drops instead of spray—cloudy or patchy make of the paper, or strong fibres that will not make a close sheet. In the last case the mottled appearance is sometimes looked for and desired, to show up a strong paper.

Paper intended for a high finish should be specially made for such if possible. The stuff should be beaten so as to produce a close sheet, with the addition of some good china clay and starch. On the machine full use must be made of the shake, and a heavy dandy roll run. If finish is wanted to be equal both sides, the paper must be run through the second press and smoothing rolls to eliminate wire, coucher and felt impressions.

Plate-Glazing.—A plate-glazed finish is applied only to high-class papers, chiefly hand-made. The plate-glazing calender is a machine consisting of a heavy frame carrying two iron rolls. Just under the level of the nip are smooth metal plates, or rollers, both at back and front. The action of the rolls is reversible and the top roll is fitted with levers to apply pressure. The sheets of paper are placed alternately with plates of copper, zinc or cardboard, until a pile, 'book' or 'handful', as it is called, is formed about 1½ to 2 inches thick. The pile is laid on the metal platform or rollers and the rolls are started. It is pushed into the nip and the rolls grip it and take it through on to the back platform. On the rolls being reversed, the pile is pulled back through the nip. It is then turned half round and the process repeated. The turning of the pile is for the purpose of reducing the curl of the plates and paper and giving the paper equal finish and expansion in the machine and cross directions.

The necessary amount of finish is obtained from the burnished surface of the plates, the pressure and the number of times the pile is put through the rolls. High finish is given by copper or zinc plates, low finish by cardboard. One man works the machine, but it is sometimes necessary to have an assistant turning the pile at the back for low finishes and helping to lift a heavy 'book' from the bench. Women are employed to lay the sheets of paper and metal and to separate them afterwards. A plate-glazed finish is very fine and silky, and the most permanent of all finishes. An extremely high glaze may be put on the paper, but if overdone the sheet may be crushed out of all recognition. In any case, specks of dirt are shown up very prominently. One may look through hundreds of sheets without finding a single one that is faultless in this respect. Unless trimmed, the edges of a plate-glazed sheet are slightly rougher than the centre, owing to the difficulty of laying the paper and metal plates so that all the edges coincide.

Plate-glazing is a very expensive method, owing to the labour and time required, and the extra broke made by the necessity of handling the sheets so often. The hands of the workers are very frequently cut and scratched by the plates, and if a slight injury is not immediately noticed, a great deal of paper may be spoiled by blood-stains. The crew of a machine consists of four women or girls, with the attendant and an assistant. Practically the only papers that are now plate-glazed are hand-made papers, and some super-quality machine-made writing and ledger papers. The special qualities of silkiness and close texture necessary for the smooth gliding of the pen point cannot be equalled by any other finish, and its permanence is one of the special features of a super-quality ledger paper.

While there will always be a certain but limited demand for expensive plate-glazed paper, this method has to all intents and purposes been superseded by the super-calender; the finish given by this machine satisfies most ordinary requirements. Hand-sized sheets, both hand- and machine-made, are also finished by putting them one by one through a pair of iron or iron and composition rolls, steam heated, and weighted when necessary. After a pile has been put through, the sheets are half turned and then put through a second time. This is a cheaper method, as two women do the work. The paper thus treated is usually sold as 'plate-glazed'. It may be confidently stated that only an expert can tell the difference between a plate-glazed and a carefully super-calendered finish, and that only when he has good samples of each for comparison.

Linen-faced and other finishes are produced by the same means as described for plate-glazing, except that a sheet of linen of the desired texture is stuck on to the zinc plate or laid between the plate and the sheet of paper. When the 'book' is passed through the rolls, the pressure causes the linen threads to make an impression on the paper, and the linen-faced effect is produced. The impression is much greater when the linen is new, and it gradually wears away as the linen becomes flattened. These papers appear to be losing popularity at present, but they are very pleasant to write upon. The cost of linen facing is high on account of the amount of labour required and the slowness of the operation, and also the high cost and short life of the linen.

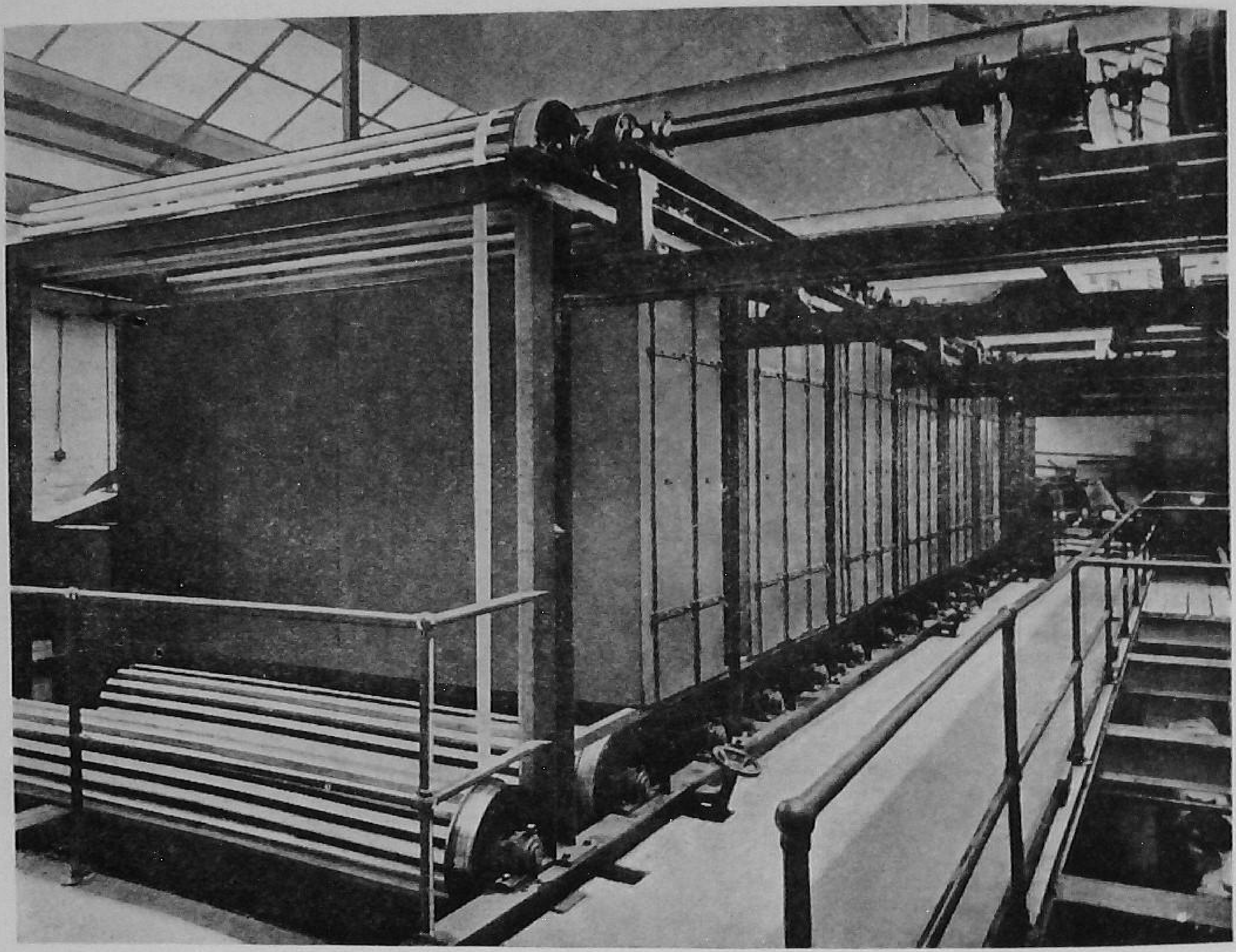
For cheaper papers an embossing calender is generally used. This contains a roll with a linen impression etched upon its surface. The paper is run through in the same way as through a calender and the process is very quick and less costly. The result, however, is not so satisfactory. The embossing calender may be used to give all kinds of 'finish' to paper, such as 'watered silk', imitation leather and names, designs, which in some cases are almost indistinguishable from water-marks.

Paper conditioning, or maturing, as it is sometimes called, has come into considerable prominence during the last few years, and is one of those additional processes which have been forced on paper-makers by the demands of the printer, who in his turn has been forced to seek for paper which will give him trouble-free running on his fast-running automatic machines. To put it very simply, paper conditioning consists solely in getting paper 'into balance' with what has been termed a 'normal atmosphere', which is generally accepted as being an atmosphere of 65° F. temperature and 65 per cent relative humidity. In an atmosphere such as this there will be

approximately 3·45 grains of water as vapour in a cubic foot of air, and this corresponds to a moisture content in the paper of between 6 and 7 per cent. Paper which is composed principally of cellulose is hygroscopic—that is, it will take in or give up moisture according to the conditions of the air in which it is placed—and it will alter in moisture content comparatively quickly. This fact is responsible for waviness on the edges of the finished paper. In the majority of mill-finished Fourdrinier papers the moisture content of the finished paper as it is reeled up varies considerably, and can be as low as 1·5 per cent and as high as 4·5 per cent according to the surface given—a very highly finished paper which has been run over hot calender rolls may contain very little moisture; on the other hand, an offset paper which has had less rolling may contain the higher percentage. It is impossible to give any definite figures on this because of the factors which govern this content at the reel end. It will be apparent that the paper is deficient in the moisture necessary to bring it up to the balance with normal atmosphere mentioned earlier. Provided that a normal atmosphere has free access to the paper over the whole of the sheet for about 15 minutes the sheet will of its own accord absorb sufficient moisture for it to arrive at its correct moisture content. Under general mill conditions, however, this free access is not given to the paper; it is reeled, cut, sorted, and packed, and during the whole of that time it is in bulk, and in consequence moisture can be absorbed only by the outside edges of the paper. In the case of a ream it will be obvious that the centre of practically every sheet of that ream will be unable to get air. The outside edges, however, are exposed to the atmosphere and absorb moisture. The absorption of moisture causes the paper to expand, and because that expansion is held back by the unexpanded centre portion of the sheet, the edges develop into a series of waves, and it is this waviness and irregular tension in the sheet which causes the printer so much trouble. Paper-conditioning machines are now available for dealing with this, and all work on the same principle—namely, of passing the continuous web through a controlled atmosphere which will impart sufficient moisture to the paper in its passage through the machine to bring it 'into balance' with the normal atmosphere. The illustrations, Figs. 212 and 213, show the latest type of conditioning plant made and supplied by Messrs. Hall & Kay of Ashton-under-Lyne.

Cutting.—It is very seldom now that we find a cutter attached to a making machine, but this was once not uncommon. As the old type of cutter, known as the 'English' or single sheet cutter, was limited in speed to under 65 feet per minute, it was found to be uneconomical to keep back the speed of the

machine to suit the cutter. There are still some machines, however, with this cutter attached. These are used for making and cutting high-class



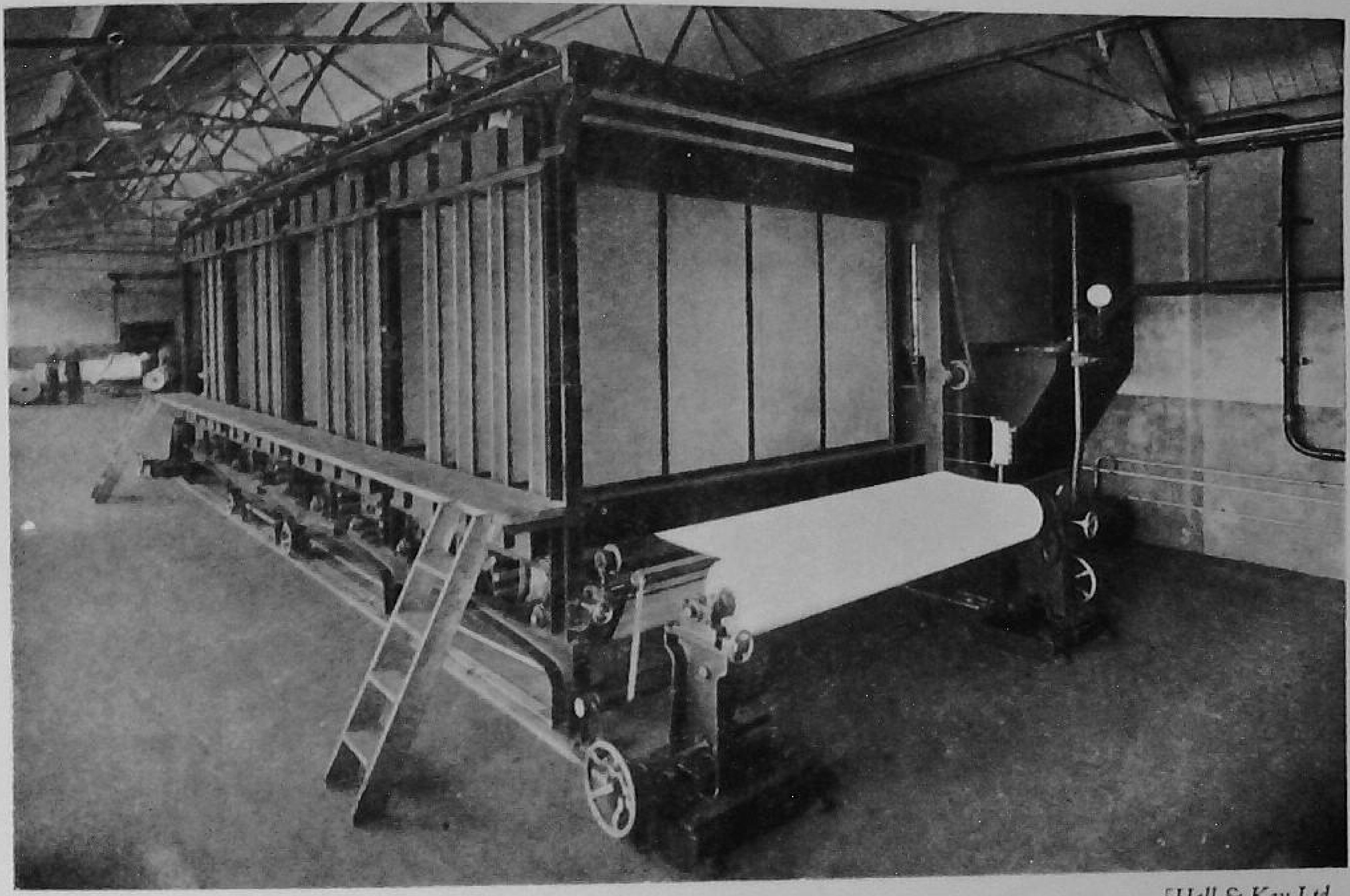
[*Hall & Kay Ltd.*

FIG. 212.—HALL & KAY CONDITIONING PLANT FOR THE CONDITIONING OF PAPER IN ROLLS PRIOR TO CUTTING OR SLITTING

writings and drawings 'water-leaf', the sheets being subsequently hand-sized with gelatine, and as a high speed cannot be attained with these papers the objection does not apply.

The 'English' cutter consists of the usual slitting discs or knives which are common to all cutters, and a reciprocating action chopper. After being slit longitudinally, the paper is run over a large drum. This drum is moved round, carrying the paper to the required length of sheet. The slit sheets fall over a 'dead' knife, and are temporarily clamped as the moving blade swings away and the action of the drum is stopped. The return swing of the blade shears off the sheets, which fall on to a moving felt or smooth inclined surface and are 'laid' by hand by boys. The web slackens back at each stop or clamping, and the slack is taken up by a 'dancing roll', the tension being regulated by two large cone pulleys. The length of the sheet is set by a

screw adjustment in the crank which moves the drum, and slight variations are made by hanging small weights on the 'dancing roll' and by a brake



[Hall & Kay Ltd.

FIG. 213.—HALL & KAY CONDITIONING PLANT, SHOWING A COMPLETE UNIT WITH SPARRED ROLLS ROUND WHICH THE PAPER PASSES TO GIVE IT PLENTY OF AIR

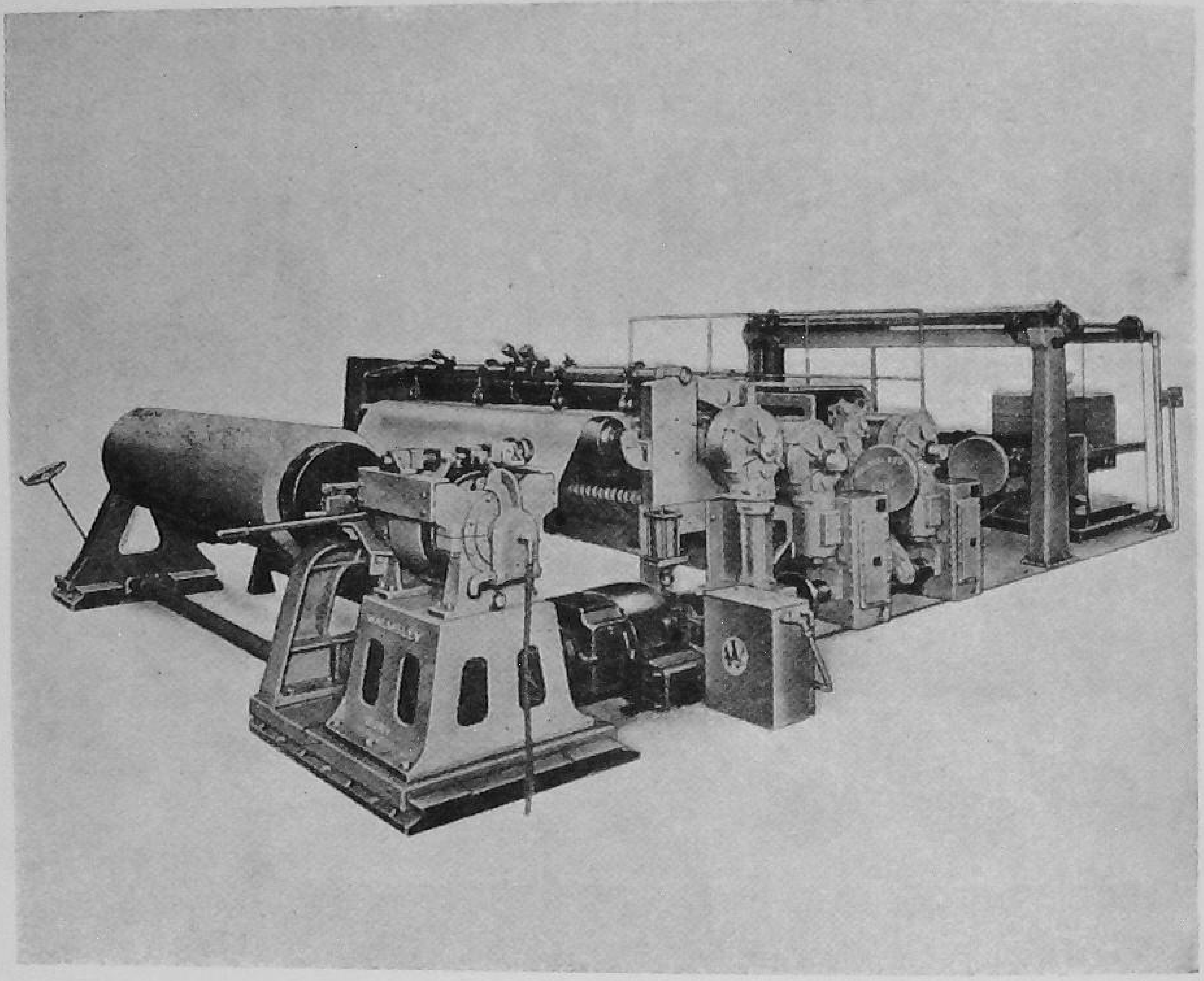
which checks the momentum of the drum. A change of gear wheels enables the crank to make two forward movements of the drum for one chop of the knife for very long sheets.

When cutting short sheets, the speed has to be reduced to under 45 feet, owing to the vibration and the jar of the reciprocating parts. Only one web can be cut at a time. This type of cutter is very accurate in capable hands, and some may still be found doing good work in cutting water-marked papers which must be in exact register.

Under modern conditions of speed and output the revolving cutter (Figs. 214, 215 and 216) is now used. The chop knife is fixed on a revolving drum, thus eliminating the reciprocating action altogether. For very short sheets two knives may be used on the drum, but this is seldom carried out in practice, the usual procedure being to cut double sheets and cut them in two on the guillotine cutter.

As many as twelve or more sheets or webs may be cut at one time, according to the thickness of the paper. If the filling is too heavy the bottom

sheets may be torn instead of being cut with clean edges. Two rolls thickened at the centre pull the paper into the slitter discs. The tension between the



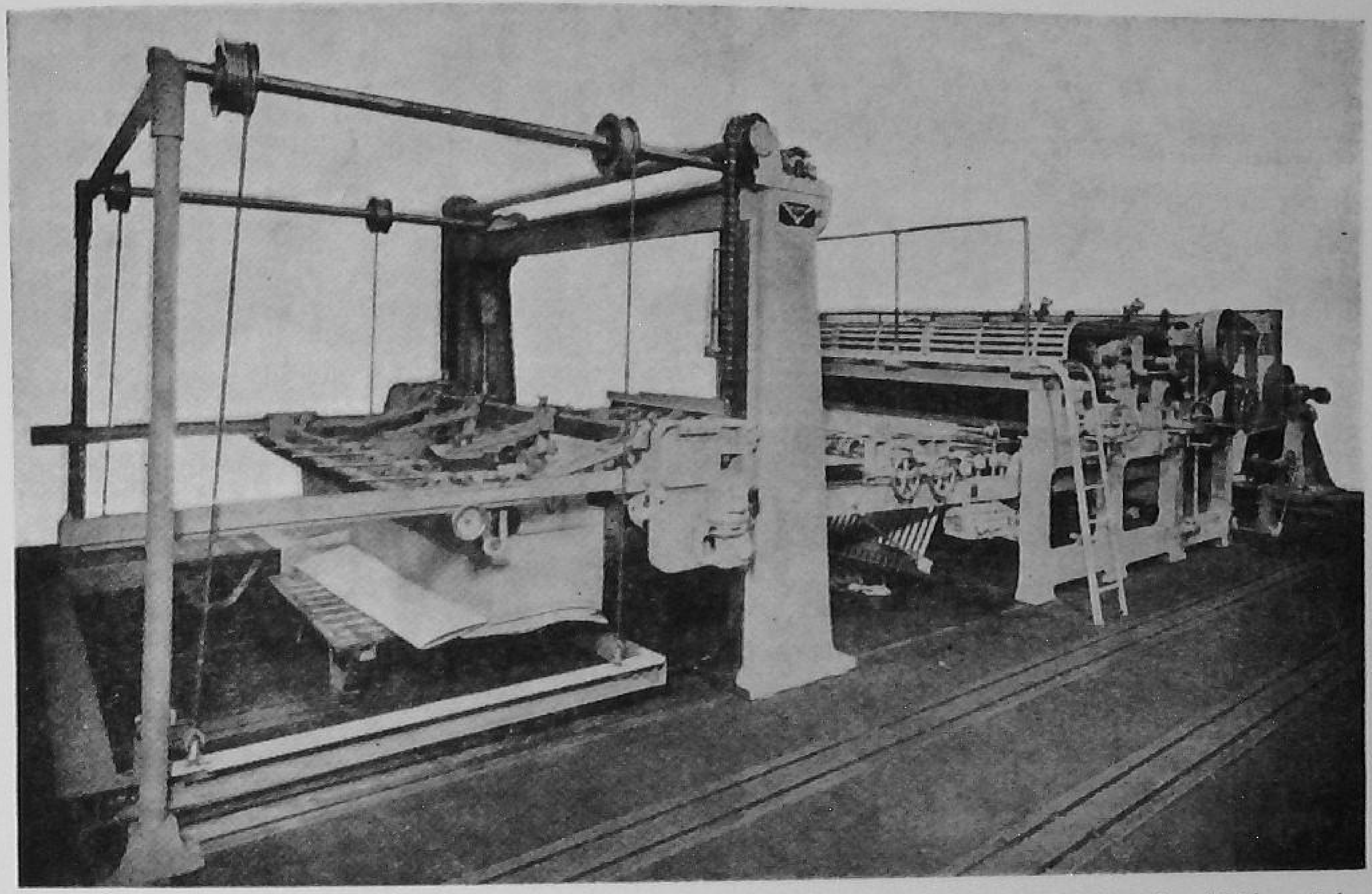
[*Walmsleys (Bury) Ltd.*

FIG. 214.—A MODERN HIGH-SPEED CUTTER WITH ENCLOSED GEARS

feeding rolls and the discs is maintained by two steel rolls about 3 inches in diameter. These deliver the slit webs on to the dead knife edge. The knife on the revolving drum, set at a slight angle so as to have a shearing effect, chops the sheets as they pass over the dead knife, and they fall on to a moving felt. The length of the sheet is regulated by the speed of the revolving drum. This is set by changes of the driving pulleys or gears, and finer adjustment is made by expanding pulleys, enabling water-marked papers to be cut to register.

The carriage of the revolving drum and dead knife is adjustable to cut the sheets at a true right angle to the slit sides. This device is extended so far in the 'angle' cutter that sheets may be cut at any angle. This is essential for reducing waste in stamping out envelopes, etc. A very useful variation of the ordinary cutter is the Duplex cutter, which can cut sheets of different sizes from the same web. This enables the paper-maker to make full use of the width of the machine. Thus, if the machine is capable of making only

72-inch deckle, and the order is for sheets 30×40 inches, the lot may be made one sheet 30 inches and one sheet 40=70 inches, instead of 2 sheets



[*Walmsleys (Bury) Ltd. and Vickerys Ltd.*

Fig. 215.—Vickery Lay-Boy at the end of a Walmsley High-Speed Cutter

30 inches=60 inches. The Duplex cutter has two revolving cylinders and dead knives. These may be driven independently and at different speeds, one part of the web passing over the first revolving knife and being cut at a different length by the second.

An invention which has reduced the labour costs of the cutter to a great extent is the automatic 'layboy'. Formerly it was necessary to have a boy to 'lay' each sheet as it came off the moving felt, so that a cutterman and five boys was a usual cutter crew. With this device which 'lays' and 'jogs up' the sheets automatically, a cutterman and an assistant can manage a cutter.

A cutterman must be very careful and precise with his work. The setting of the slitting discs is a very simple matter. The distance between each fixed disc is accurately set with a good rule, preferably steel. The moving disc is then brought into contact with the fixed disc, and this must be gently done, otherwise the hard edges may chip each other. Indeed, to obviate any risk of this a sheet of thin paper should be used at the point of contact.

A very common mistake is to compress the spring of the moving disc

too hard, and thus cause the cutting edges to grate on each other and wear blunt very soon. The setting of the length of the sheet is done in accordance with the table of sizes and pulleys with each cutter. The driving belt of the revolving blade must be kept in good order, and well tightened up with the tension pulley or pulleys provided for that purpose. Before starting the cutter, all tools and spanners should be accounted for and laid aside. A few sheets must be cut at full speed and carefully measured and right-angled before doing the bulk, and the edges examined from time to time for frayed or torn cuts.

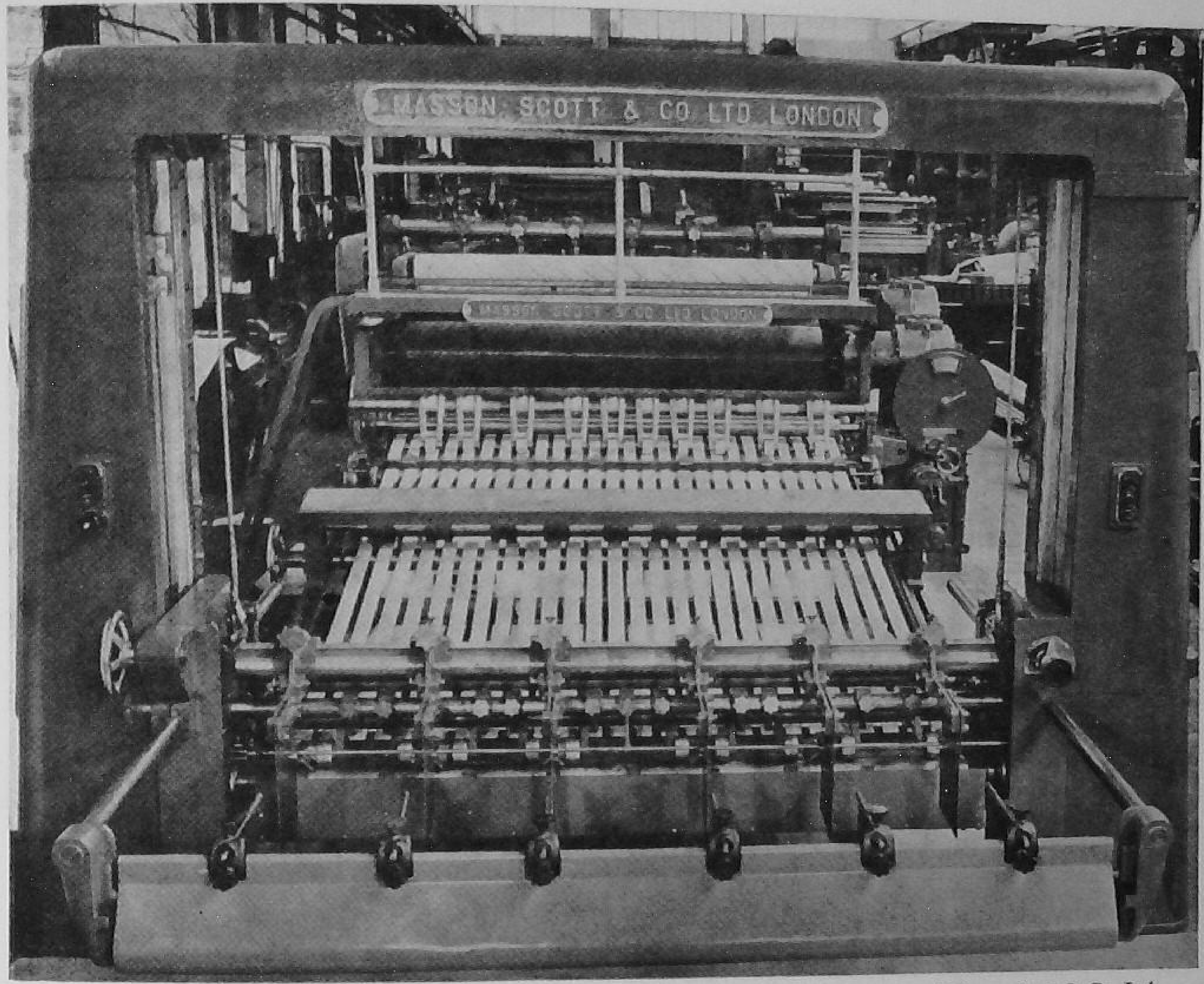
In cutting water-marked papers, the water-mark has to be kept in correct position on the sheet. This will often necessitate cutting a fraction over or under the size, as the length between the water-marks is liable to vary a little, especially in paper made on a machine with old-fashioned belt drive. A continual watch has to be kept as the sheets pass on the felt, and any variation closely followed and corrected by the skilful use of the expanding pulleys. It will be recognized that the work of the cutterman, in keeping a good and steady length, depends very much on the care taken by the machineman in setting and working the dandy and the draws of the machine. It is advisable to allow a fraction of an inch *over* the size—say, one-sixteenth—for the cut in water-marked papers.

If the dandy roll cannot be made to register exactly, the machineman should notify his foreman, and also send a slip of paper with the reel, to warn the cutterman what has occurred. If the length between water-marks is too great, the sheet must be cut to register the water-mark, and then trimmed on the guillotine. If it is too short, the water-mark will continually run out of register and compel the cutterman to throw out sheets until it comes approximately correct. It will be found on close examination that all water-marked papers cut to register have some variation in length of sheet. This is inevitable to a certain extent, and if the variation is less than ½ per cent either way, the paper may be considered commercially correct. If it is absolutely necessary to have to supply a lot the exact size, the water-mark on the dandy roll must be spaced and tensioned to allow for trimming on the guillotine.

Masson Super Cutter (Figs. 216 and 217).—This is a modern precision-built machine designed to satisfy the demand for a cutter that will operate at high speed, cut with guillotine accuracy and handle all classes of papers efficiently, whether thick or thin. Cutting speeds of 600 feet per minute and over are attained.

The machine comprises a heavy feeding press and cutting unit mounted on robust side frames. The feeding press rolls are of special composition, ensuring that all the webs of paper are fed uniformly to the cutting unit.

The latter, which is adjustable for true square cut, is driven through a positive, steplessly adjustable gear which controls the speed of the rotating



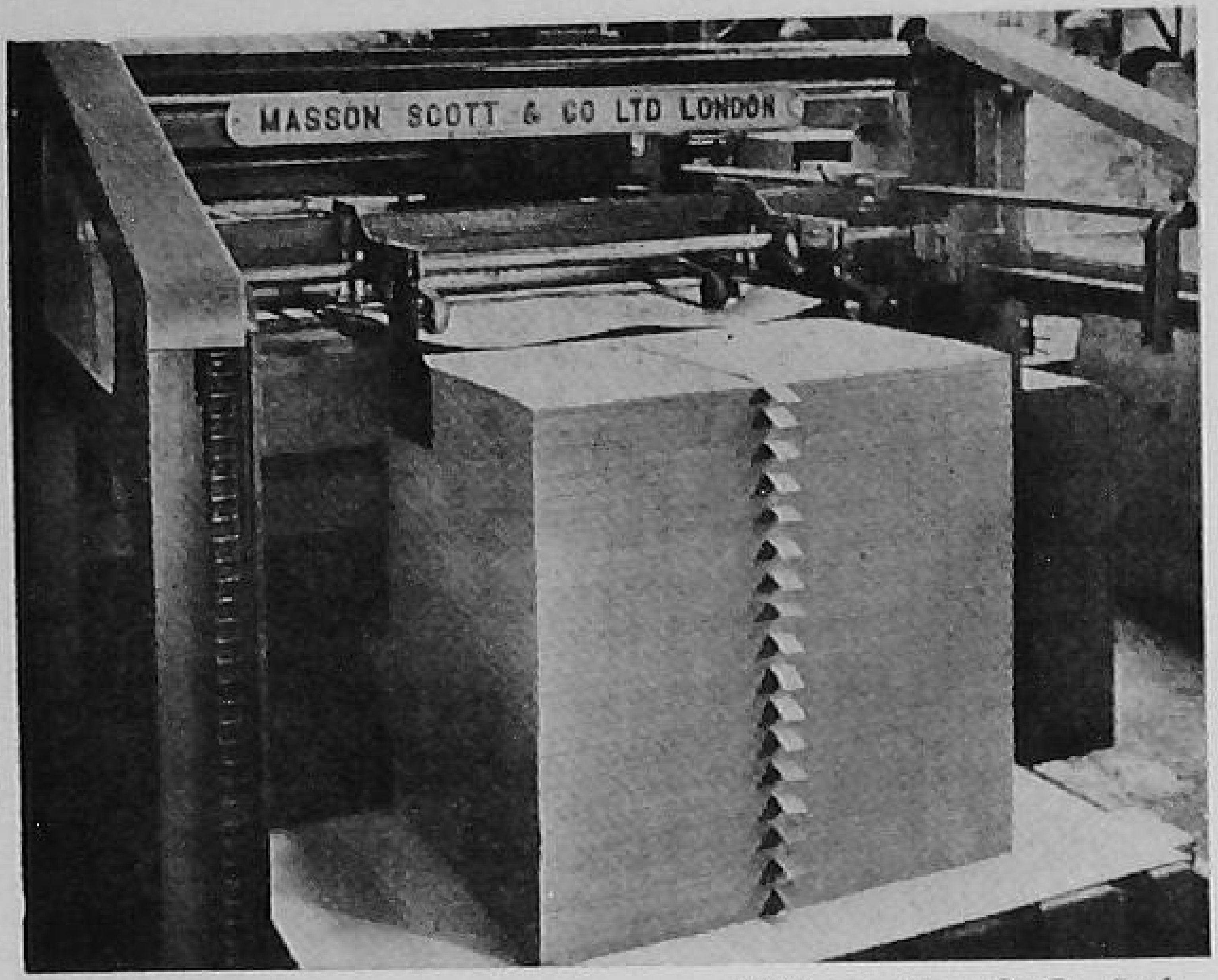
[*Masson Scott & Co. Ltd.*

Fig. 216.—Latest type High-Speed Precision Super Cutter, showing Tapes and Lay-Boy

knife and thus enables the length of the cut to be accurately regulated. The drive for the entire machine forms a totally enclosed unit which is mounted on the cutter frame. Every step in the drive is positive so as to avoid back-lash, all main drives being effected through totally enclosed, precision, chrome-nickel steel bevel gears mounted in roller and ball bearings. The machine is direct motor driven through an electro-magnetic coupling which incorporates an overload safety device and an automatic brake for stopping the cutter as soon as the motor is switched off. The whole of the equipment, while massive and robust throughout, is built more on the lines of modern high-speed printing machinery than is customary in paper-mill equipment.

The slitter gear, which is situated in front of the feeding press, is provided with knife holders of a new design which give an exceptionally wide clear-

ance for feeding through the sheet. The bottom slitter knives, mounted on a stiff one-piece shaft, are made in halves so that they can be readily changed to enable each pair of slitter knives, and therefore the width of each slit web, to be adjusted simply by turning one handwheel, the width of the web being read off on a graduated scale.



[*Masson Scott & Co. Ltd.*

FIG. 217.—STACK OF SHEETS COUNTED, TICKETED AND LAID AUTOMATICALLY ON THE MASSON SUPER CUTTER

On leaving the cross-cutting unit the sheets are transported to the layboy on a system of conveyor bands. With the latest design of feed the paper run is entirely horizontal right through the cutter. This facilitates handling and helps to prevent turned-up edges, particularly at high speeds, when cutting only one or a few webs, and also in handling light-weight papers.

The automatic hydraulic overlapping layboy enables the high speed of the cutter to be taken full advantage of. It is actuated by oil under pressure supplied by a pump driven by the main motor. The speed of the layboy carriage is first adjusted to suit the thickness of the bundles of paper by means of a handwheel, and thereafter the layboy carriage rises automatically as the height of the stack increases. When the layboy reaches the top of its run it is lowered to the starting position in 2 or 3 seconds by simply opening a valve. As the sheets are delivered from the cutter to the layboy they are overlapped like tiles on a roof, so that they can reach the stack at only a fraction of the speed at which they have passed through the cutter. The sheets are thus easily controlled on the layboy and are not liable to be damaged by the stop board. A system of air nozzles above the layboy conveyor facilitates handling light-weight papers, and a further series of air nozzles at the end of the layboy float the sheets gently into position on the stack. The cutter and layboy are controlled entirely from a central push-button panel. A number of extra 'stop' push-buttons are fitted at convenient points about the machine to enable the operator to stop it from whatever position he may be in.

There are designs for simplex, duplex and triplex cuttings, while models are available for installation at the end of a board machine for which the new slitter gear with single handwheel adjustment is used so that the width of slit

can be altered while the machine is running. On the duplex cutters a special coupling is fitted to disengage the duplex unit when cutting simplex only, and an automatic hydraulic stack equalizing device is provided to compensate for the unequal height of the stacks when cutting duplex.

Recently various auxiliaries for these cutters have been developed. Chief among these is a push-button-operated attachment on the drive to the rotary knife drum, enabling the length of cut to be varied by small amounts to locate the water-mark on the cut sheet. Registration of the water-mark is controlled by an operative as he stands at the layboy and watches the overlapped sheets passing to the stack. With this equipment water-marked papers are being cut accurately to register at speeds of nearly 400 feet a minute. The ream counter and tabber counts the sheets in reams of 480, 500, 516 sheets as required and inserts a coloured paper strip between each ream. This is all automatic.

When handling papers which are liable to give trouble due to static electricity, the electric neutralizer has proved extremely useful. It discharges the static electricity in the paper during its passage through the cutter, enabling the latter to be run at higher speeds and minimizes broke. It is quite safe for the operatives and takes practically no current.

It is usual to employ duplicate sets of reelstands so that one set of reels can be loaded while the other set is being run off on the cutter. According to the space available, various methods are used for bringing the new set of reels into position for feeding into the cutter. Where the two sets of reel bearings are arranged horizontally behind the cutter, one above the other, the top set of reels is loaded by an overhead crane in the usual way while the bottom set of reels is being cut. While the top set is being run off, the bottom set is loaded in position by a trolley running on track rails arranged between the stands. The trolley is provided with hydraulic raising and lowering gear.

By another method the two sets of reelstands are mounted on a turntable which is rotated by hand or by an electric motor to bring a fresh set of reels into position. In one case the sets of stationary reelstands have been mounted side by side, and the cutter mounted on a travelling carriage, enabling it to move sideways from one set of reelstands to the other.

The Guillotine.—The guillotine is an essential part of the cutting equipment. Its function is to trim or subdivide sheets cut by the rotary cutter. It is the only cutter used in a 'hand-made' mill. It consists of a heavy frame supporting a level table, on which the sheets are placed. A cutting or shearing blade works diagonally in upright guides. In close contact with the cutting blade is another blade which is blunt on its lower edge. The latter

is worked by a foot lever, and is pulled down on the handful of sheets, holding them firm and solid, close to the proposed line of the cut. The cutting blade slides down in contact with this blade with a sideways and downwards motion, similar to that which is made by a knife held in the hand. At the same time power is added to the clamp, to fix the paper more firmly.

The mechanism is so arranged that only one chop or cut is made by the action of pulling over a lever. The blade then ascends, and stops at the top of the guides, and the holding blade is released. The action is assisted by the momentum of a heavy fly-wheel, which is automatically thrown out of action when the knife ascends. An upright at the back of the table is movable to take the required size of sheet. The distance from this upright to the cut is indicated by a sliding gauge at the side of the table, or by a gauge worked by a steel ribbon. A side plate at right angles to the back plate is also provided to enable dead square trimming to be done. By means of this machine sheets may be trimmed and cut dead square, or 'slit' into small sizes. Small sheets are usually cut double on the rotary cutter and cut into two on the guillotine.

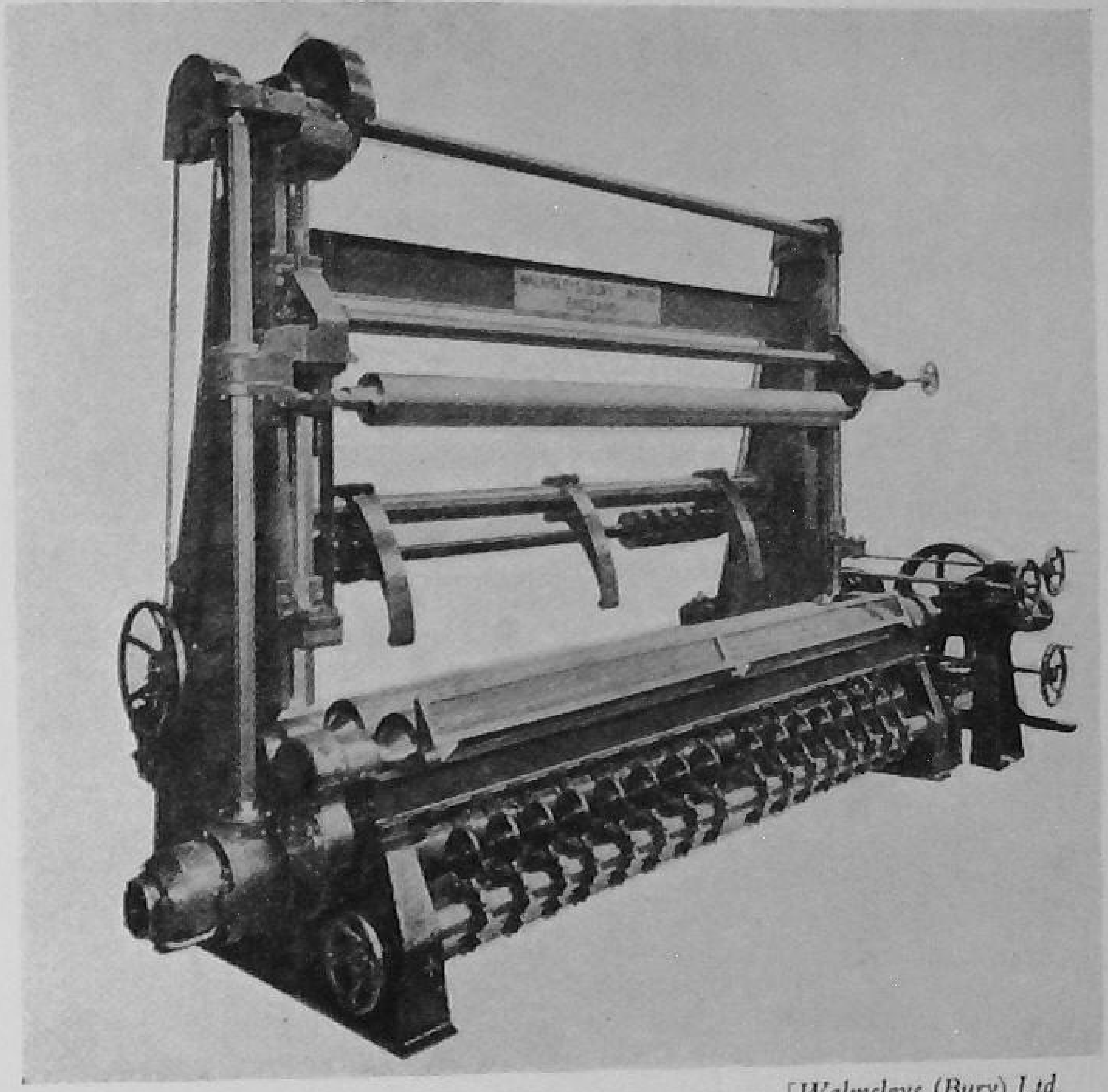
A very common size cuts 40 inches and requires about $2\frac{1}{2}$ h.p. for 'handfuls' of about 4 inches thickness. Smaller sizes are used by stationers, who get their paper in bulk and cut it into writing and ledger sizes.

Webs, Slitting and Winding.—As more printing and other processes are being made continuous, the demand for paper in webs or reels in place of sheets is increasing and likely to increase. For this reason the production of paper in reels is becoming of more importance in every paper-mill.

A good reel of paper should be evenly and cleanly slit, and run up to the required size or length with no breaks, cracks on the edges, hard or soft places, or unequal substance and finish. All these cannot be obtained if the paper is poorly made and finished, and faults which would not be apparent in paper cut into sheets become very obvious when it is wound into reels. In the first place, the wire and clothing of the machine must be in very good order. Ridges or dirty streaks on the wire, uneven spread of stuff at the slices, worn or scored couch roll covers, dirty wet felts, badly-cambered rolls, dry felts that have become worn and thin in the centres, unequal couching, pressing, drying, damping or finishing are the most usual causes of bad reeling.

Variations in substance are difficult to check, since the paper machineman is handicapped by the fact that he must not spoil a web by tearing out and weighing sheets, and has to keep correct substance by other means. An experienced machineman will, however, come very near to being exact by keeping in close touch with his machine. At the end of every reel a piece the whole width of the machine should be taken and sheets marked and cut

from the centre and both sides, so as to cover all the width of the paper. Damping and drying should be specially watched, since the success of the



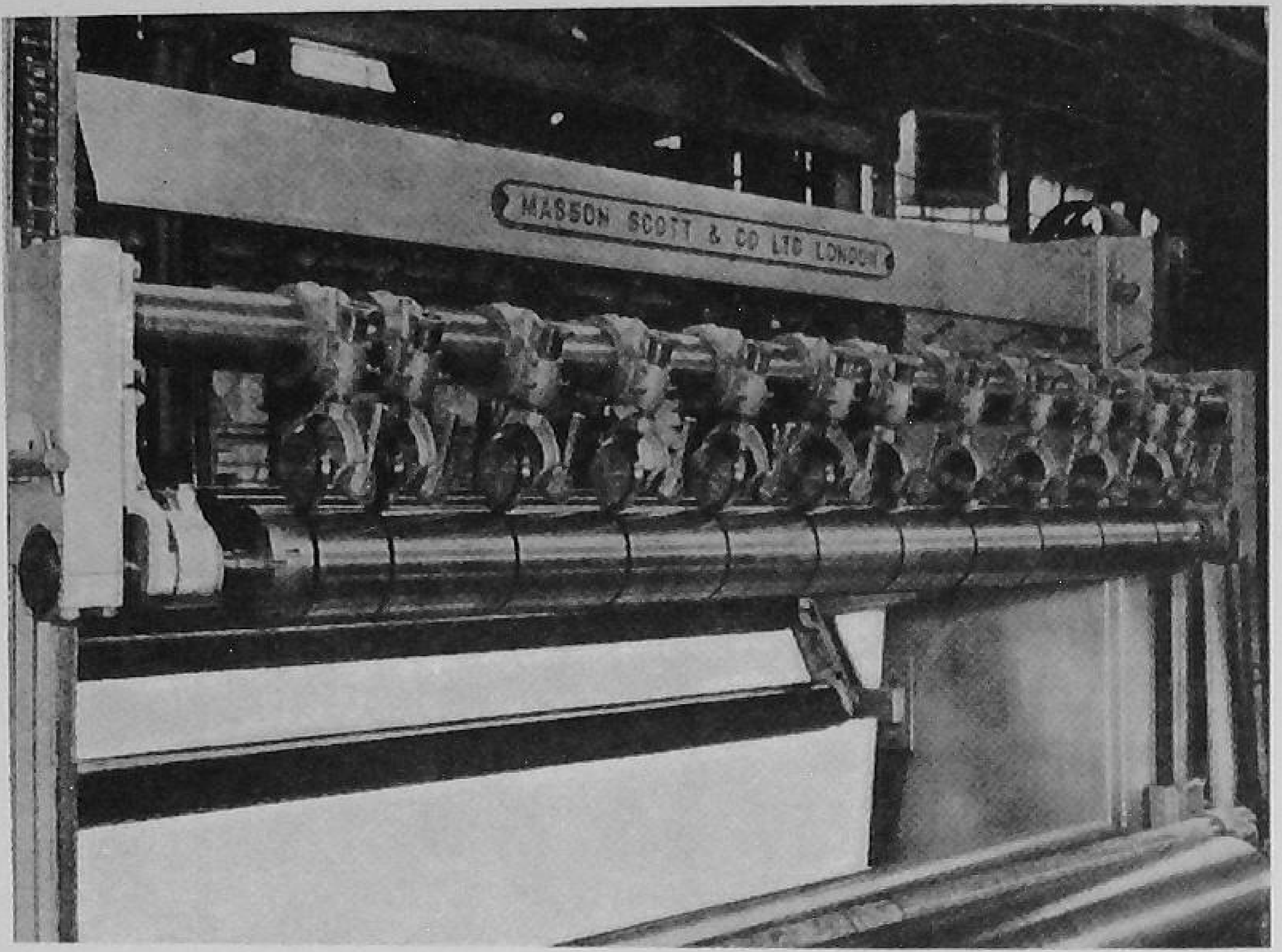
[Walmsleys (Bury) Ltd.

FIG. 218.—HIGH-SPEED DRUM REELER EQUIPPED FOR SLITTING A LARGE NUMBER OF NARROW REELS

super-calender finish will depend on this being regular all across the web. A slight extra damping at any one place will produce a higher finish, which will show as a soft place when reeled. This may be easily so serious as to cause the paper to be creased on the slitter and winder.

Slitters and Winders (Figs. 218 and 219).—These are of two kinds, friction and drum winders. The friction winder has slitter discs, which are identical with the rotary cutter discs and slit the paper in the same way. Each slit web is wound on a separate spindle by a friction arrangement similar to that on the making machine. This is not a very efficient machine, since the tightness of the web depends entirely on the strain the paper will stand without breaking, so that the webs are soft and bulky. They are therefore very liable to damage in transit and become lop-sided on standing or being packed. This causes breaks on the printing machine, as the result of the jerky motion of the unbalanced reel. The drum winder, as its name implies, winds the web by contact with one or two cylinders by its own weight, and is regulated by levers at the spindle ends. As the weight of the

web increases, the paper is pressed harder to the cylinders and wound tighter, which is the reverse of the friction type, where the pull of the



[*Masson Scott & Co. Ltd.*

FIG. 219.—HIGH-SPEED PRECISION SLITTER AND RE-REELER, SHOWING THE CUTTING EQUIPMENT

friction has less effect as the web increases in diameter. The weight of the levers is so applied that the web can be partly supported to ensure regular pressure from the start to the finish of the reel. In the drum winder all the slit webs are wound on one spindle, strawboard centres of the requisite width being put on the bar and kept tight and in position by an expanding device. The paper is wound by the action of two cylinders travelling close together in the same direction, the webs being in contact with both. The cylinders are sometimes spiralled on the surface, outwards from the centres, to reduce the chances of creasing. If only one cylinder is used, the web is pressed against it by means of levers at the spindle ends, or else it runs directly on top of it. When it is necessary to reel two webs of different yardage a four-drum winder is used. By this means two webs of different lengths may be run off at the same time from the same reel.

A very simple and efficient winder has a cylinder about 9 inches in diameter formed of sections which fit on to a centre. These segments are of various lengths so that slitting knives in the form of thin steel discs may be introduced between them at the required distances. The whole is fixed by screws and lock nuts at each end. Cutter discs cut the side shavings, but the actual splitting takes place on the cylinder on the top of which the web

is run. This machine, sometimes called a ripper, has the advantage that the split edges cannot run into each other, the cutting discs protruding from

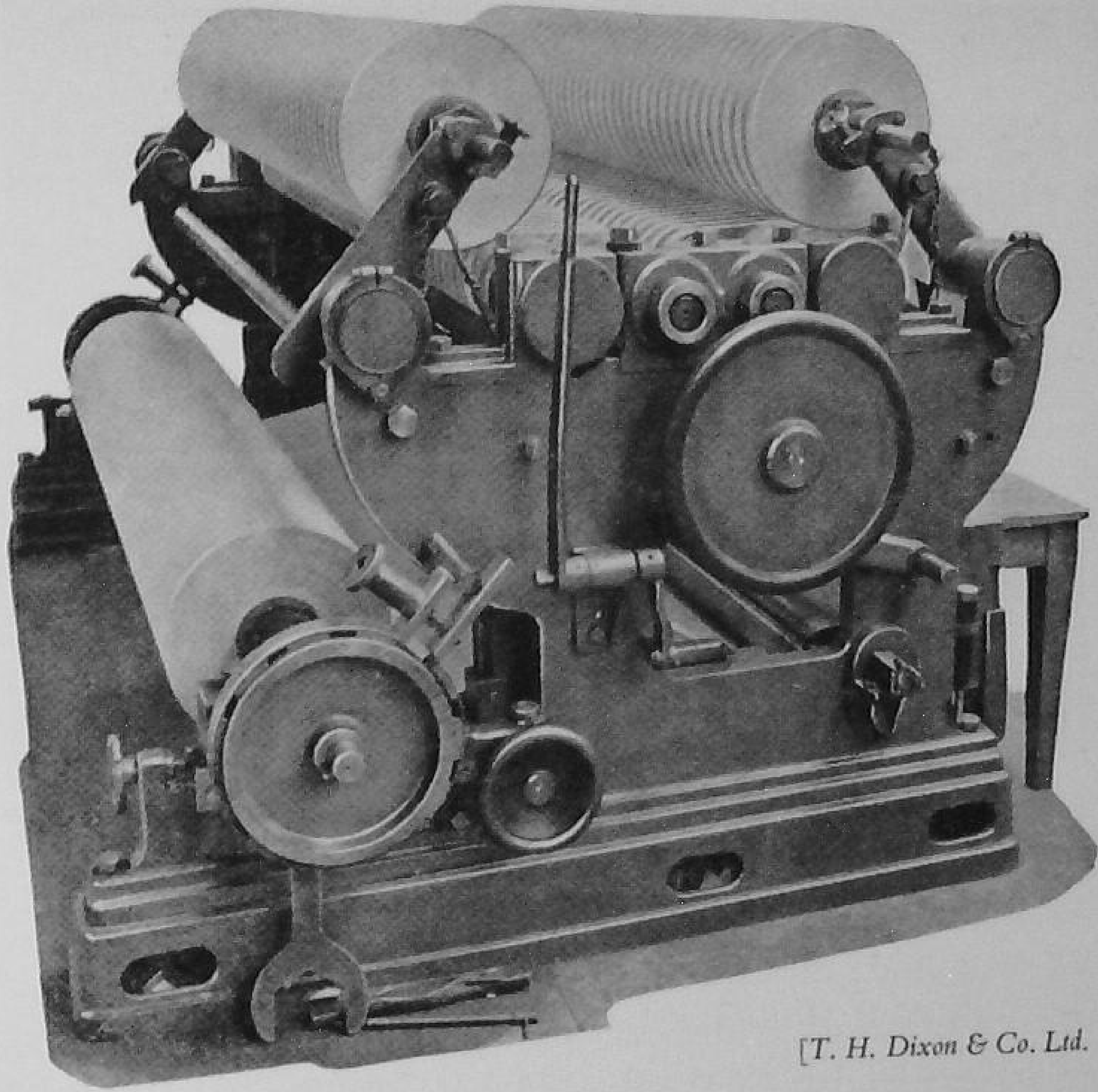
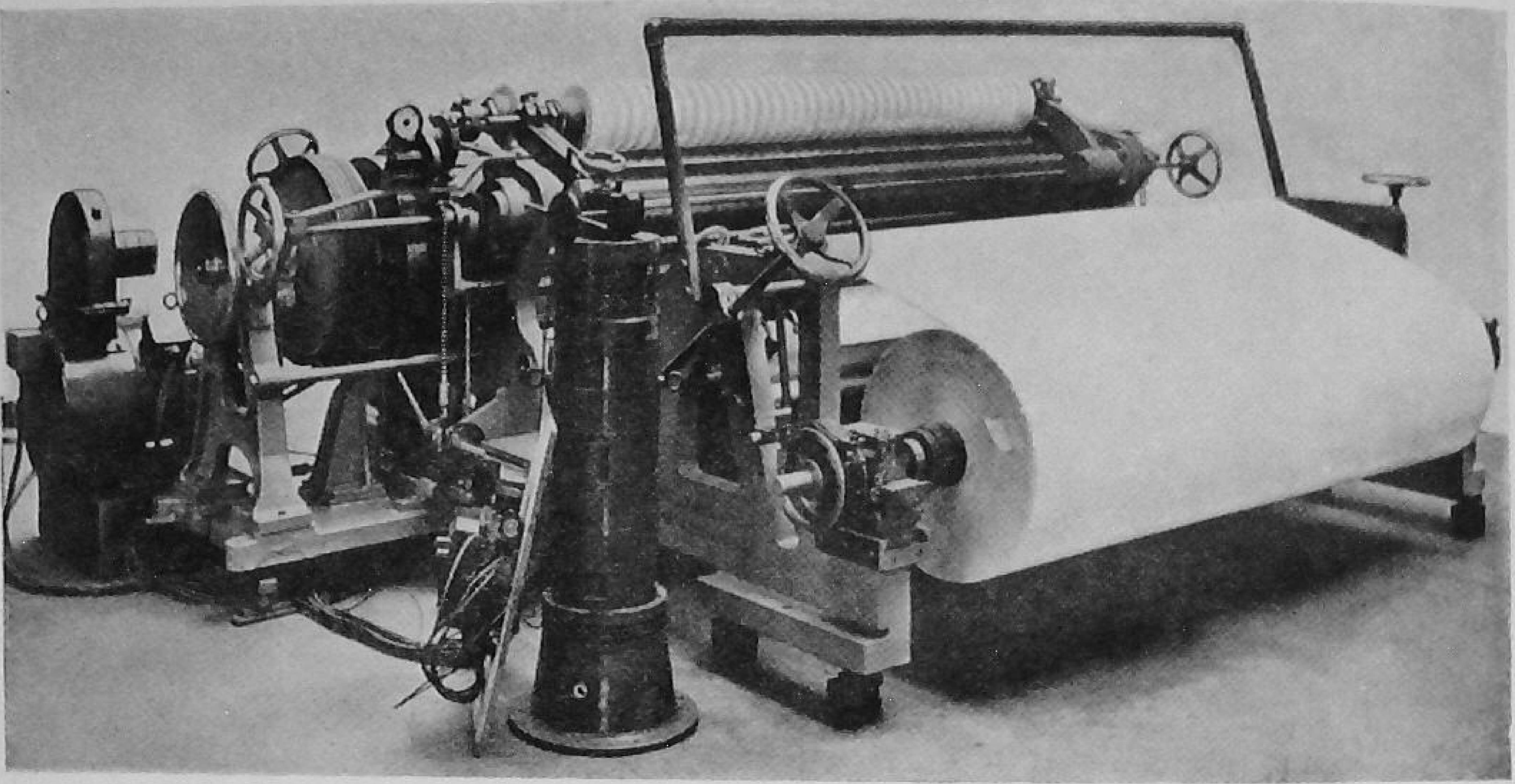


FIG. 220.—NARROW COIL SLITTER WITH CRUSH CUT KNIVES AND DRUM REEL-UP

the cylinder about $\frac{1}{4}$ inch. On winders where all the splitting is done by ordinary cutter discs it is often a matter of difficulty to prevent the cut edges of adjacent webs interlocking. It is usual to have a flexible steel bar over which the paper is dragged, and which is bent by set-pins by the attendant into such shapes as to keep the cuts open. On other winders the slitting is done by means of small steel discs attached by rocking levers suitably weighted to a cross-bar. They are movable sideways on the bar for adjusting to the breadth of the web required. Being fixed between two circular plates $\frac{1}{2}$ inch less in diameter, they are thereby kept from being jammed in the cut by the pressure of levers, and in contact with the web coming off the drum. An attachment which is almost indispensable for a winder is an indicator showing the length of paper that is wound. Immediately the webs are taken off the winding spindle, hard wood plugs should be driven into the open ends of the centres to prevent the pressure from

buckling them inwards, as the outside edges of the paper swell by absorbing atmospheric moisture, unless conditioned.



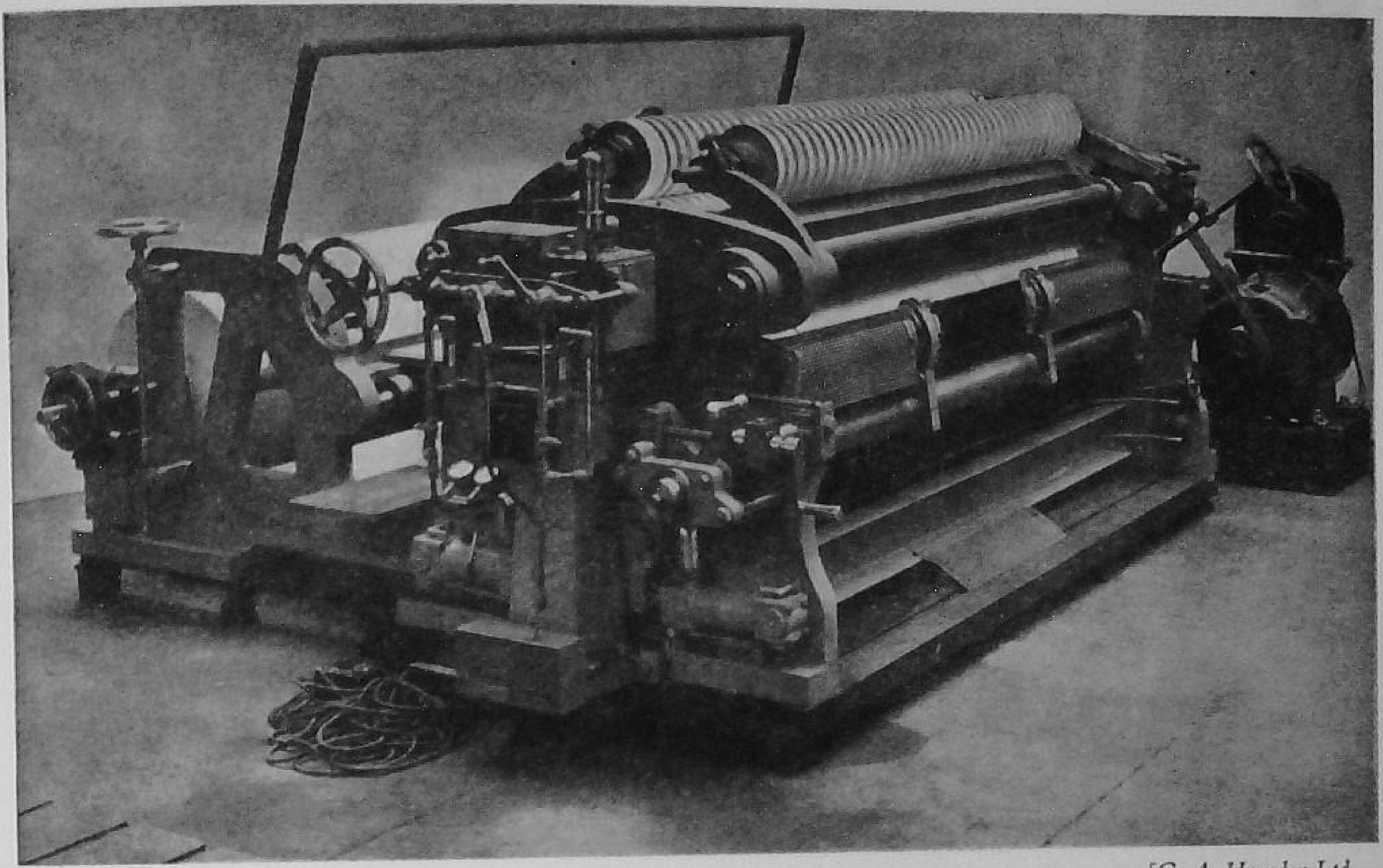
[C. A. Harnden Ltd.

Fig. 221.—High-Speed Precision Narrow Bobbin Slitter and Reeler for Cutting and Reeling Narrow Coils at High Speed direct from Jumbo Roll, showing Driving and Control Gear

When a break takes place the winder is stopped, the broken edges are cut square and joined with gutta-percha tape or paste. A hot iron is pressed over the join to dry and fix it, and a slip is put in to indicate its presence. A piece torn from the edge should also be marked in the same way. In order to run good tight webs, such as will run off well on the newspaper presses, it is essential that the webs should be tightly wound from the start, and all joins must be very carefully made, especially at the edges. Walmsley and Masson Scott machines are excellent for this work.

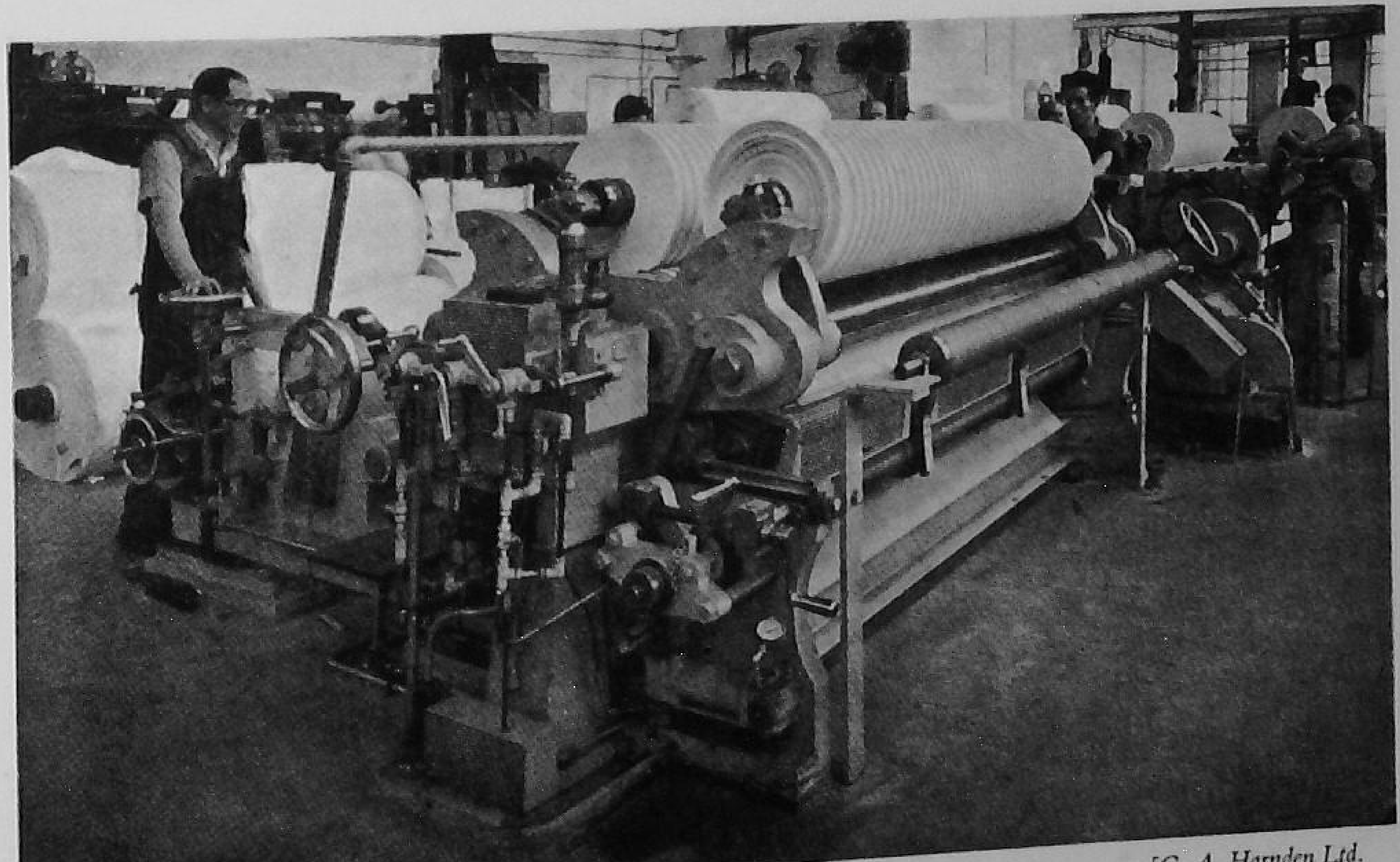
A new type of very high precision slitting machine has recently been manufactured by Messrs. C. A. Harnden Limited. These machines are made up to about 80 or 90 inches wide, and are capable of slitting machine rolls without intermediate re-reeling at very high speeds into very narrow coils of absolute accuracy. These machines have been used with great success in slitting bobbins of cigarette paper, where it is necessary to slit to within a $\frac{1}{4}$ mm. The cut is smooth and clean, and there is practically no dust or fluff made during the cutting operation. This machine is illustrated in Figs. 221, 221a and 222.

An automatic brake is fitted to the parent roll, enabling the machine to be stopped very quickly if required without the roll over-running, and



[C. A. Harnden Ltd.

FIG. 221A.—HIGH-SPEED PRECISION SLITTER, SHOWING THE HYDRAULIC GEAR FOR LIFTING THE ARMS. ALSO, WITH GUARD REMOVED, THE POSITION OF THE DISH-TYPE SLITTING KNIVES



[C. A. Harnden Ltd.

FIG. 222.—FRONT VIEW OF HIGH-SPEED PRECISION SLITTER, SHOWING HYDRAULIC MECHANISM FOR RAISING FULL BARS OF COILS. THESE SLITTERS CUT ACCURATELY TO HALF A MILLIMETRE

there is an excellent type of spring-loaded dancing roll which enables the feed to be kept very constant. The hydraulic gear lifts the full bars of coils,

[R. Fletcher & Son, Ltd., Greenfield Paper Mill

FIG. 223.—SORTING, JOGGING, COUNTING AND PACKING TISSUE PAPER INTO REAMS

which are wound alternately on the left and right shafts, clear of the drums for unloading and stripping. The cut is done by means of a male and female knife, and each male knife is spring-loaded to hold it in position against the spacers. This cut is more satisfactory than the crush cut usually employed, as the edges of the coils are much smoother.

THE SALLE

Sorting and Finishing (Figs. 223, 224 and 225).—After the paper has been cut it passes to the 'salle' or finishing room to be overlooked by women sorters, who remove damaged or faulty sheets, and it is then 'told out' or counted by tellers in reams containing a certain number of sheets, after which it is weighed, tied up and put into store, or packed up in bundles of two or more reams and dispatched to the customer.

Obviously this sorting department is a very important place, and calls for very strict and careful supervision if the good name of the mill is to be

preserved. Generally speaking, the finer the qualities of paper being made the more careful must the sorting be, for while a few specks of dirt may not

[R. Fletcher & Son Ltd., Greenfield Paper Mill

FIG. 224.—EXAMINING, CLEANING, BANDING, AND PACKING BOBBINS OF CIGARETTE PAPER

be of much consequence in a sheet of cheap printing or wrapping paper, they cannot be allowed to pass in a sheet of good writing paper.

In the sorting room of a mill the light must be good, and must come in through windows facing north if possible, otherwise blinds will have to be arranged on the windows to lessen the glare of the sun. It is always best to get most, if not all, of the overhauling or sorting done during the hours of daylight, and this is of paramount importance if the paper contains different shades which have to be picked out and packed separately. The girls generally stand at benches with the pile of paper to be sorted on their right-hand side. In front of them they lay the good or perfect sheets, which they 'jog up' periodically into a neat pile. It is usual to have an arrangement of bricks or wooden elbows, in order to form a kind of frame into which the size of paper being sorted will fit. This helps to keep the pile straight and tidy. If they are sorting three grades—'good', 'retree' and 'broken'—they will need to make three piles, the good in front of them, the retree over on the left-hand side and the broken at the back. Finally, the bad or useless sheets,

such as those with holes, creases and pieces torn off, may be put in a basket, or anywhere else convenient, ready to be taken away to the beater room to be used over again.

[*Wiggins, Teape & Co. Ltd.*

FIG. 225.—WELL-APPOINTED AND WELL-LIT SALLE FOR FINISHING, COUNTING AND PACKING FINE PAPERS

According to trade custom good or perfect paper is paid for at full price, retree at an allowance of 10 per cent, and broken, if taken, at an allowance of 20 per cent. The question as to what constitutes a good sheet and a retree sheet must be decided before the paper is sorted, and this is usually done by the salle foreman or forewoman in conjunction with the manager, several factors having to be taken into account. In the first place, the paper must be equal to the sample, subject to the price being paid for it, and subject also to the known requirements of the customer.

The sorters, who must have experience, while referring doubtful questions to their forewoman, use their own judgment as to what shall constitute a good sheet, and any sheet which does not quite reach this standard is placed on one side to be sold as retree. Those which contain blemishes in the third degree are put among the broken, and obviously faulty and useless sheets are sent back to the mill.

So far we have dealt only with dirt or blemishes in the paper, and these may consist of all kinds of foreign matter, such as pieces of metal from the

beater knives, chips from buttons, etc., small pieces of rubber, specks of improperly dissolved dye, splinters of wood, shive, shine, froth and many other things. Besides dirt, there are other things which may spoil an otherwise perfect sheet of paper; and the women must be on the look out for light or heavy sheets, which must not be allowed to pass, sheets which are too low or too high in finish, and those in which the water-mark is defective, or, in the case of a paper in which the mark has to register, if this is out of place.

In 'jogging up' the sheets the sorter will observe those sheets which are not cut square, or are too long or too short, or cut with ragged edges.

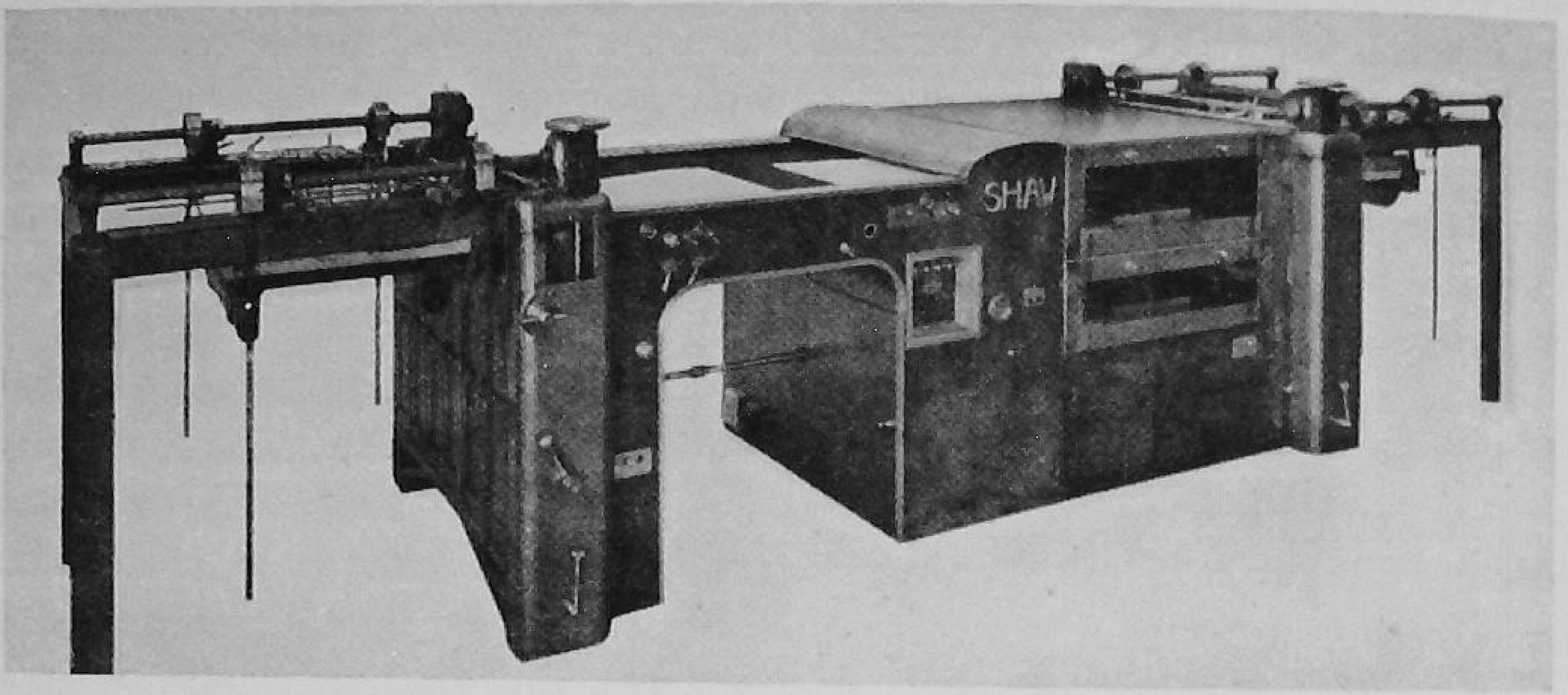
From the foregoing remarks, it will be seen that the sorters' work requires experience and skill, and, above all, great care and concentration. A good sorter works at a very fast speed, and rarely allows a faulty sheet to pass, so that she is a valuable asset to the salle, and gets the best qualities to overlook. New sorters gain their experience on lower grades of paper, which do not require such careful sorting. It is usual for good-class papers to be turned as they are being sorted, so that both sides of the sheet can be examined, and during the turning movement the appearance of the 'look-through' of the sheet and also the water-mark can be seen. In this way crushed sheets, and blurred or otherwise imperfect water-marks, can be seen and thrown out.

It often happens that a small piece of wire, forming part of a letter or design, becomes detached from the dandy roll, and this may not be immediately observed at the machine, so that, unless the sorters are very careful and skilful in watching the mark, they may let through a quantity of paper with the defective mark, and if it is detected by the customer the paper is quite likely to be rejected.

In the sorting of water-marked papers for postage stamps and security papers, which are needle-cut and have to register exactly, it is necessary for each sheet to be placed in a frame with a glass back, in order that its exact registration may be carefully checked.

In order that the work of sorting may be thoroughly and carefully carried out, there must be adequate supervision of the sorters by capable forewomen, whose duty is to watch the sorters regularly, check their work by occasionally re-sorting it, and removing any faulty sheets which may have slipped through unnoticed. It is also very necessary to watch that a sorter working very fast does not crumple the sheets by rough handling. Many sorters otherwise efficient and careful have this fault, which is mostly the result of gripping the sheets too tightly with the left hand.

Paper Sorting and Counting Machine.—Recently a new machine (Fig. 226) has been put on the market for mechanically passing sheets of



[John Shaw & Sons (Honley) Ltd.

FIG. 226.—THE 'HOLM DALE' PAPER SORTING MACHINE

paper in front of a sorter and eventually counting the reams of perfect paper while rejecting, on pressing a button, the retree and broken sheets. A machine of this description has long been badly needed in the paper trade, and it is hoped that this machine will be found to be the answer, and that it will take away a lot of the irksome drudgery of sorting and counting reams by hand.

The paper to be sorted is brought straight to the machine on the same stillages on which the paper is delivered from the sheet-cutting machine; the stillages can be wheeled into the feed-end either from the side or from the end (whichever is most convenient) and by means of a special raising and lowering device the height of paper can be adjusted to the level of the suction feed. A similar automatic device keeps the height of the paper constant with that of the feed rollers whilst a further device at the delivery end enables the delivery pile to be kept constant with the height of the delivery rollers.

When the paper is in position the machine is started up and a special type of suction feed delivers the paper, sheet by sheet, on to a moving blanket. As the sheets are conveyed on to the blanket they are momentarily and automatically halted for inspection by an ingenious application of the suction principle; the operator has complete control of the speed at which the sheets move (as well as the period for which the sheet is halted) and can slow the speed down to 50 feet per minute or increase it to 250 feet per minute simply by operating the variable speed handwheel control which is

within easy reach. If the sheet is satisfactory it is automatically delivered on to the stillages at the delivery end of the machine; if it is retree or broke the operator presses the relevant button and the sheet is automatically delivered to a rejection box, of which there are two—one for retree and one for broke—neatly situated inside the machine in convenient positions for easy unloading. The sheets passed by the operator are automatically counted by an electronic device; this can be set to any number between 0 and 2,500; when the desired number is reached this is signalled to the operator by means of a pilot light as well as by an audible signal.

The machine can be operated by any disabled or other person who has a knowledge of paper sorting. The present machine is available to take any size of sheet up to 40 × 40 inches, but in future it is proposed to make machines capable of taking sheets up to 60 × 60 inches. The machine is very well designed and very strongly constructed, and great care has been given to the mechanical details. It seems as if this machine should be very useful to paper-makers, converters and printers.

After the paper has been sorted it is carefully jogged, and stacked ready to be counted into reams. The counting or telling is quickly done, usually by women, who turn over the edge of a handful of paper and run their fingers across the edges of three, four or more sheets at a time. Often it is necessary to 'quire mark' the reams, and in this case a slip of coloured paper is put in after every twenty sheets. Unless the paper is specified all 'insides' or each quire perfect, it is usual to place a quire of retree at the top and bottom of each ream, so that if the paper is slightly marked or creased by the tape or during handling, it will generally be the retree quire which will suffer.

As soon as the reams are counted they should be weighed and packed in ream wrappers and fastened with gummed tape; they are then marked as required. Usually a special brand label is pasted to the ream wrapper, and in this case the wrappers must be thoroughly dried before being used, so that the wet paste will not break through and cockle the paper inside.

When reams are tied with tape the operation should be neatly and regularly carried out, so that when the reams are placed in a pile all the tapes will correspond and give a neat appearance. Attention to these details always helps to give a good name to the mill. In some cases gummed tape is used for closing the ream wrappers, but this has the disadvantage that it necessitates a fold of wrapper being placed over on to the top of the ream, instead of being folded in at the end, which does not make such a neat package. When proper knots are used to tie up the tape, the reams can be unfastened quickly and without spoiling the wrapper when only a sheet or a

quire or two are required, or when the paper is being examined at the buyer's warehouse. Before the paper is sent away it is usual to tie up two or three reams into a bundle, and this is done by means of strong and bulky wrappers, in order to protect the paper from damage in transit, and to lessen the handling and packing of it in trucks or lorries.

It is important that valuable papers should be well and securely packed, and sufficient attention is not always paid to this important point. A good paper is worth a good wrapper and will always benefit from it. To realize the importance of this it is only necessary to visit the warehouse of one of the large wholesale stationers, and see the conditions in which the consignments of paper arrive from different mills. Some are neat and untorn, while others are often untidy and the wrappers are all torn and gaping, exposing the paper to light, dust and moisture. While some damage can no doubt be attributed to rough handling in transit, it will generally be found that the packing is greatly to blame. In the case of large and unwieldy reams, especially if the paper is thin in substance, it will be necessary to pack the bundles between light wooden frames or boards, in order to prevent the reams from bending and buckling when being loaded and unloaded. Formerly, this method was adopted with most fine papers, but nowadays it is generally confined to special lots and unwieldy sizes. These boards and frames are the property of the mill in most cases and are returnable.

Various methods of packing have to be adopted for shipment of paper to the Continent and for export. Water-proof lined cases have to be provided for gummed paper for postage stamps, and the lining is usually of zinc; the top layer of zinc is soldered down when the case is full. Other packings require the paper to be baled in a hydraulic press between strong boards with wire hoops.

The overhauling, counting and packing of all other qualities of paper are the same as those for fine writing papers already described, except that the same standard of cleanliness is not usually expected, and cheaper forms of packing and tying up are used. Wrapping papers, news off-cuts and cheap papers generally do not have wrappers extending over the ends. In the case of large sheets which cannot conveniently be handled flat, they are folded once or twice, making a more compact and rigid bundle.

The loading of reams and reels of paper into lorries or railway wagons must be very carefully carried out. Straw should be placed on the floor and this should be *dry*. The truck or lorry should be filled as full as possible, so that the reels or reams have no room in which to slide about, and all reels should be securely scotched to prevent rolling. Considerable damage is often

done in transit owing to the goods not being properly packed by the sender. Another very general cause of spoilage is the carriage of paper in lorries or railway wagons that have contained coal or other dirty or oily material. It is here that the value of a mill siding is apparent, as railway trucks can be examined and swept clean, and if the floors are uneven, a few sheets of coarse wrapping may be laid down to protect the reels or packages. Mill lorries should be similarly treated.

CHAPTER XXV

THE TESTING OF PAPER — TRANSPARENCY AND OPACITY — DURABILITY AND STORAGE OF PAPER

THERE are a great many features which require to be considered in the testing of paper as usually carried out at the mill or in the mill laboratory. We have no intention of trespassing on the sphere of scientific research, or of describing intricate processes, but simply to give such information as will be readily understood and ample for commercial purposes.

In the making of all papers it is obvious that some standard for *quality* must be aimed at, and before going further we must define what we mean by *quality*. This expression as applied to paper is capable of a very wide definition; literally, a paper of 'high-class quality' is one made by hand from the best materials, such as new rags; sized by hand, loft-dried and possibly plate glazed, and, in fact, a paper of superlative excellence. In the broad sense of the term, however, a paper may be of excellent quality, no matter what its composition, provided that it is eminently suited for the purpose for which it is to be used.

Newsprint, for instance, may be described as of very high-class quality, and the term may be perfectly correct and logical, though it cannot be said that newsprint, as paper, is of high quality.

Therefore, in testing or judging quality, some standard is necessary for comparison, and as a basis on which to found a judgment. This basis, as between the paper-maker and his customer, is generally defined in terms of price and a certain sample to be matched, this sample being mutually agreed upon at the time the order is placed.

It often happens, however, that a prospective customer sends a sample and wishes to know the price at which it can be matched. Occasionally, too, instead of a sample, a general indication of the kind of paper required is given. If the paper supplied is a good match to the sample, taking into consideration the price asked for it, the customer may consider the paper to be of 'good quality'. Therefore, in testing paper, quality must be taken as a comparative term, all the characteristics of the paper being placed against those of the sample individually. For this reason it is necessary to be able to test a sample and ascertain its composition, etc., before submitting an estimate of price, and, later, for the purpose of being able to match it accurately.

Up to a few years ago—and indeed in some mills to-day—no real tests were made. The manager simply looked at the paper, rattled it, tore a corner, and perhaps compared it with some of his stock lines, and then made a guess at the price at which he could profitably match it. If the customer thought the price too high, he went elsewhere, or offered less until terms were mutually agreed upon. The paper-maker, having no real knowledge of the composition of the sample, sometimes found his paper returned as unsuitable, or was compelled to concede a reduction in price in order to get it accepted.

As trade and conditions are at present, these haphazard methods are useless. The paper-maker must know exactly the composition of the sample, and he should also know *for what purpose the paper is to be used.* He can then quote a price which, while securing more or less profit for his mill, is still low enough to stand a fair chance of securing the order against other competitors.

If his tests have been fairly accurate he need have little worry as to the results of his making, and by testing the paper at the various stages of manufacture he can check any mistake and produce a satisfactory match to the sample. But as the natural 'cussedness' of paper-making materials, machinery and workmanship may cause variations during the making of an order, provided these variations do not go very far from the sample, the paper may still, within certain limits, be called a 'commercial match'. The limits of some of the variations, such as substance, are defined by the rules of the Associations of Paper-makers and Stationers. Other variations, such as colour and opacity, which are not amenable to exact measurement, are not so defined, and are left to the decision of the customer.

This leaves openings which are sometimes taken advantage of by unscrupulous firms. A paper, for instance, may be rejected as not being an exact match to the sample for colour. This may be quite true, as it is very difficult, and in some cases almost impossible, to give an absolutely faultless match for colour. After a great deal of correspondence and argument, and threats to withhold future orders, the mill is forced to concede a percentage of the price, and the paper is then accepted. Although the paper-maker is well aware that his paper is a good commercial match, and would be considered so by a competent independent judge, he dare not force acceptance by legal action, well knowing that it may cause him serious loss of trade. Thus the importance of testing paper, so far as it can be tested with certainty, will at once be recognized.

Some of the qualities of paper, as compared to the sample, are matters of individual judgment and opinion; others are capable of being definitely demonstrated.

Constant Humidity.—It has been shown that observations on most paper tests vary widely on the same sample if tested under different conditions of relative humidity and temperature. An observation of folding endurance carried out at 70 per cent relative humidity may be double the value obtained on the same sample at 60 per cent relative humidity; it has become common practice, therefore, to 'condition' paper specimens before tests are made. The usual recognized standard atmosphere for the conditioning and testing of paper is at 65° per cent relative humidity at 65° to 70° F. It is advantageous that the paper-testing laboratory is a constant humidity and constant temperature room, having double doors with an air lock between and preferably double windows. The walls and ceiling, besides being reasonably thick and heat insulating, are better glazed or gloss painted rather than plastered, so as to reduce the water-absorbing surface to a minimum. The disposal of the paper-testing apparatus in the room must be given careful consideration, so as to avoid the room being unduly large and giving rise to difficulties with air circulation. Provision should be made to supply conditioned air into the room at the rate of about 30 cubic feet per minute per man working in the room. Temperature control of the incoming air, through the medium of a thermostat, does not present any serious problems, electrical heating of the air in winter being possibly the most convenient, and water cooling in summer where necessary, although it may be found that this latter recourse is unnecessary by careful choice of room site. Humidity control is usually brought about through the length changes of a humidity sensitive hair or a sensitized parchment strip. Constant humidity cabinets are also available in which paper specimens may lie for some time before testing in order that their moisture content may attain equilibrium with the controlled atmosphere in the cabinet.

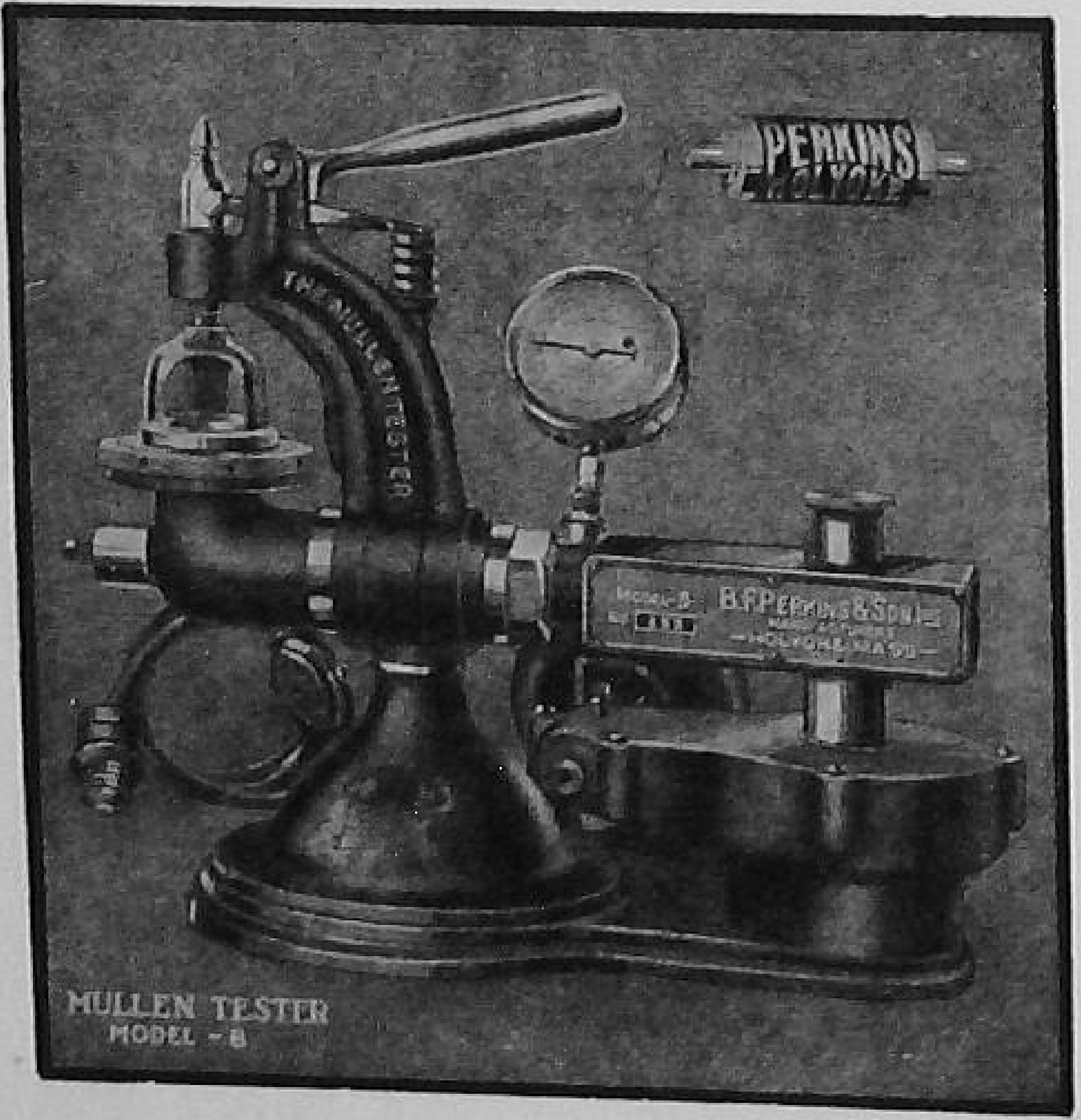


Fig. 227.—The Mullen Paper Tester for Testing the Bursting Strength of Paper

Strength.—There are several recognized appliances for testing the strength of paper. The most popular, reliable and easiest to manipulate is the Mullen paper tester (Fig. 227).

In this machine the paper is clamped over a circular diaphragm of thin rubber, 1 square inch in area. By turning a wheel, a piston forces glycerine against the under side of the diaphragm. The latter presses against the paper

with increasing force until the fibres give way and are pulled asunder. The pressure at the bursting point is recorded on a dial by a pointer.

On a sheet of large post ($16\frac{1}{2} \times 21$ inches) about 12 bursts may be taken to get a correct average. These may be 3 along each long side, 2 along each short side and 2 near the centre. The rubber diaphragms should not be used too long, as they lose their elasticity, and low readings may be expected. Generally the difference between a new and an old diaphragm may be taken as about 10 per cent, but if possible it is desirable to check results by using two testers. If the sample is tested on the same machine as the finished sheet a more accurate comparison may be made.

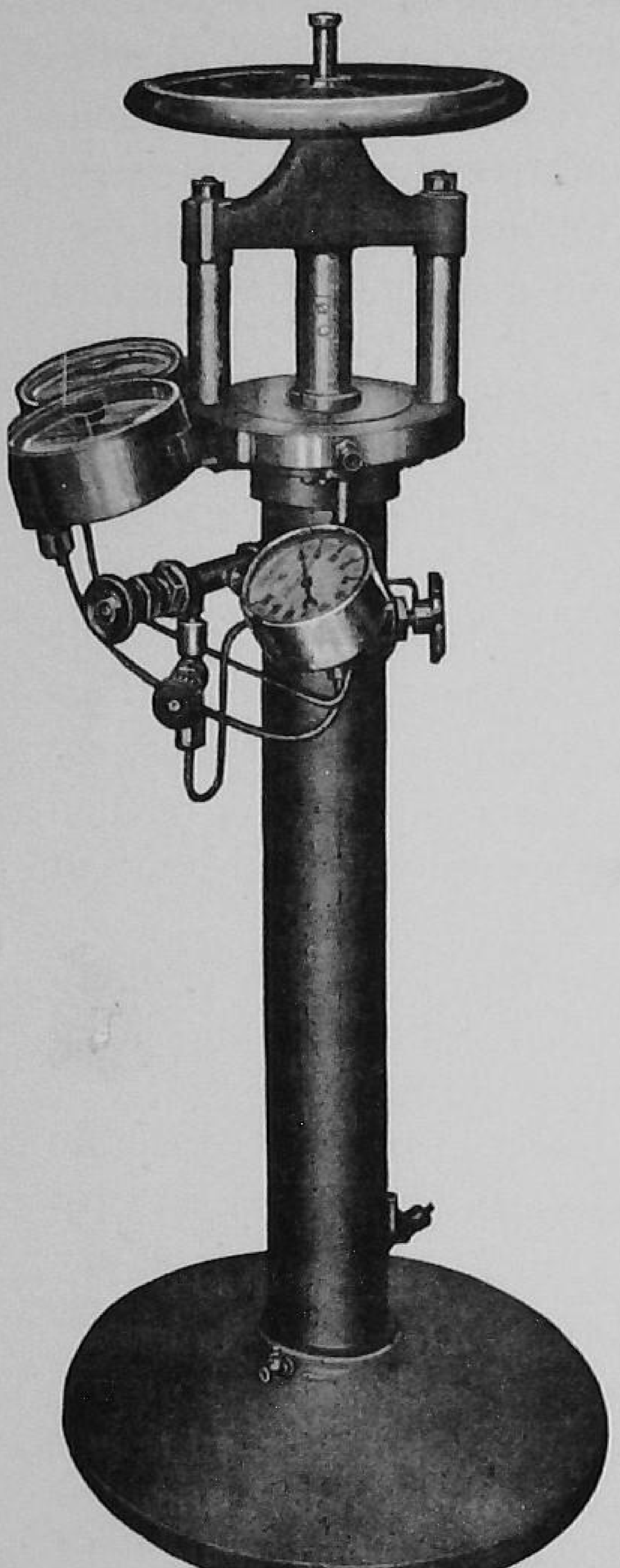
The paper must be firmly clamped, but not so hard as to produce stress on the edges of the area to be tested. The rate at which the wheel is turned produces different results. About two to three revolutions per second is a usual speed. A slower speed gives the fibres longer time under pressure, when less is required to tear them apart. A uniform, not jerky, movement of the wheel is essential. The highest bursting point of paper is reached at normal humidity, about 5 to 8 per cent moisture. If the paper is above or below this moisture content, lower readings are obtained. It is as well to remember that a paper newly made may be expected to gain up to 10 per cent increase of strength when properly matured. Sometimes different readings will be obtained according to whether the top or under side of the sheet is clamped next to the diaphragm. The sheet may be tested both ways. Two operators sometimes get different results on the same sheet, but two experienced men generally come very close in their averages.

There are other paper testers of this type, such as the Ashcroft and Schopper-Dalen, but they all work on the same principle, differing only in structural details. Certain modifications have been recommended for use with the Schopper-Dalen type of tester in the diaphragm pressure control mechanism. These are incorporated in the more recent instruments made by Goodbrand, of Stalybridge, the latest of which is illustrated in Fig. 228.

Whenever possible, the operator who tests the sample should also test the finished sheets of the paper. In connexion with these tests, it is necessary to point out that there is no corresponding proportional increase of bursting strength as the substance of the paper increases. Some paper buyers seem to be under the impression that this is so, and we know of an instance where a sample was sent to be matched for quality, but the paper had to be of a much heavier substance. When the sheets were sent in, the paper was rejected, because the bursting strain did not increase in exact proportion to the substance.

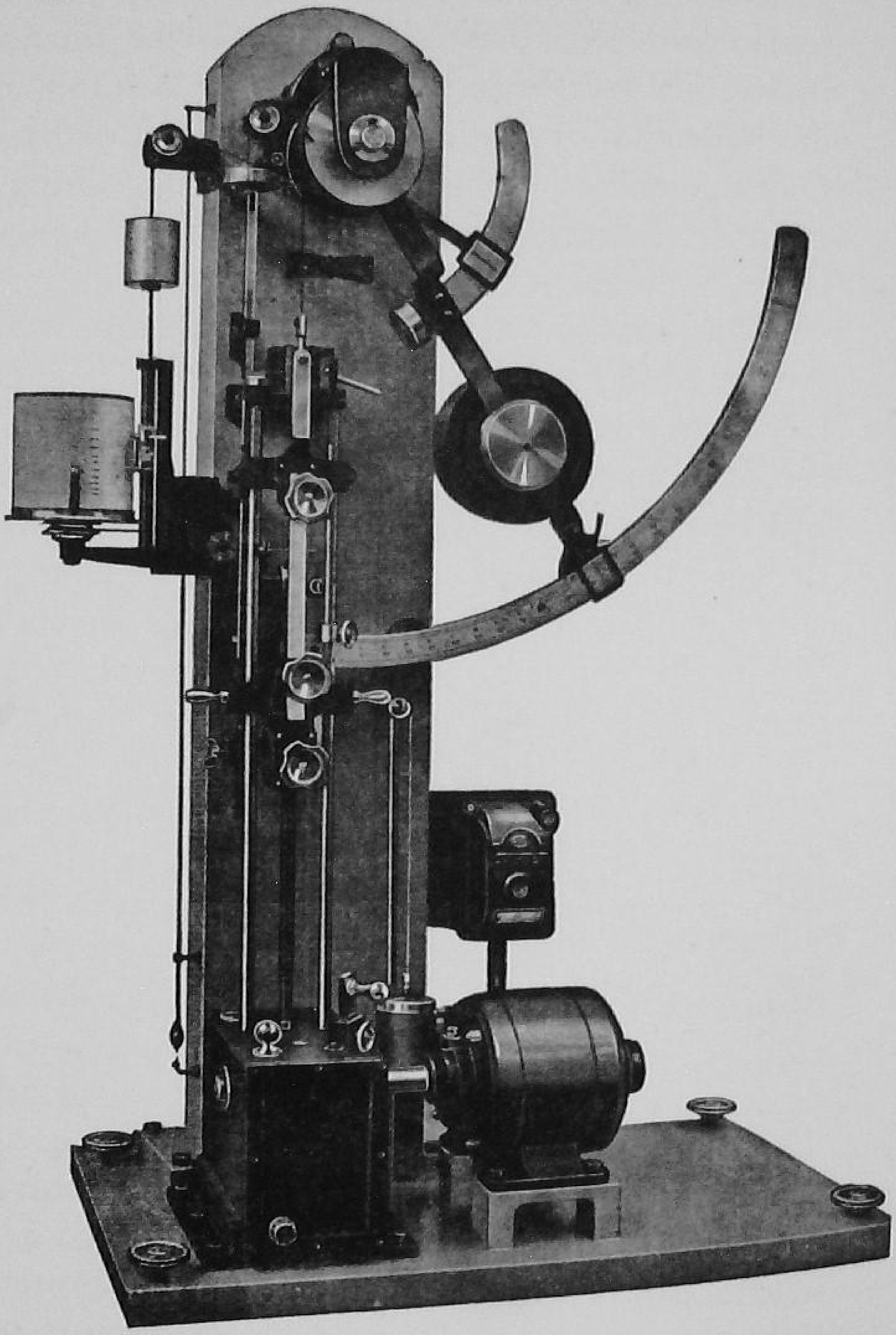
The Schopper paper tester (Fig. 229) is a modern adaptation of the old

method of paper testing. Before the introduction of this machine, a strip of paper of a certain length and breadth was suspended from a clamp; another



[Goodbrand & Co. Ltd.

FIG. 228.—NEW BRITISH BURSTING TESTER, WITH LATEST TYPE DIAPHRAGM MECHANISM



[Goodbrand & Co. Ltd.

FIG. 229.—TENSILE STRENGTH AND STRETCH TESTING MACHINE
This is the latest and most improved type and is British made.

clamp was attached to the bottom of the strip and weights were added until the strip broke. When the Schopper is used, the breaking strain of strips cut from across the web, and also in the machine direction, is taken, and a short calculation gives an average or mean breaking strain. The strip of paper, fixed between two clamps, is used to raise a heavily-weighted lever by means

of a wheel and gearing. The lever remains automatically fixed by a pawl at the point where the strip is broken, and a graduated scale and pointer show the breaking strain in pounds. In addition, the stretch which has taken place is also recorded. Like the Mullen tester, the Schopper requires the wheel to be steadily turned, and where great accuracy is required this may be done mechanically by a small electric motor, or by means of hydraulic pressure. Older machines of this type depend on a spring for the tension, and they are accurate enough on the whole, but as the Schopper machine is the standard tester, they are falling into disuse.

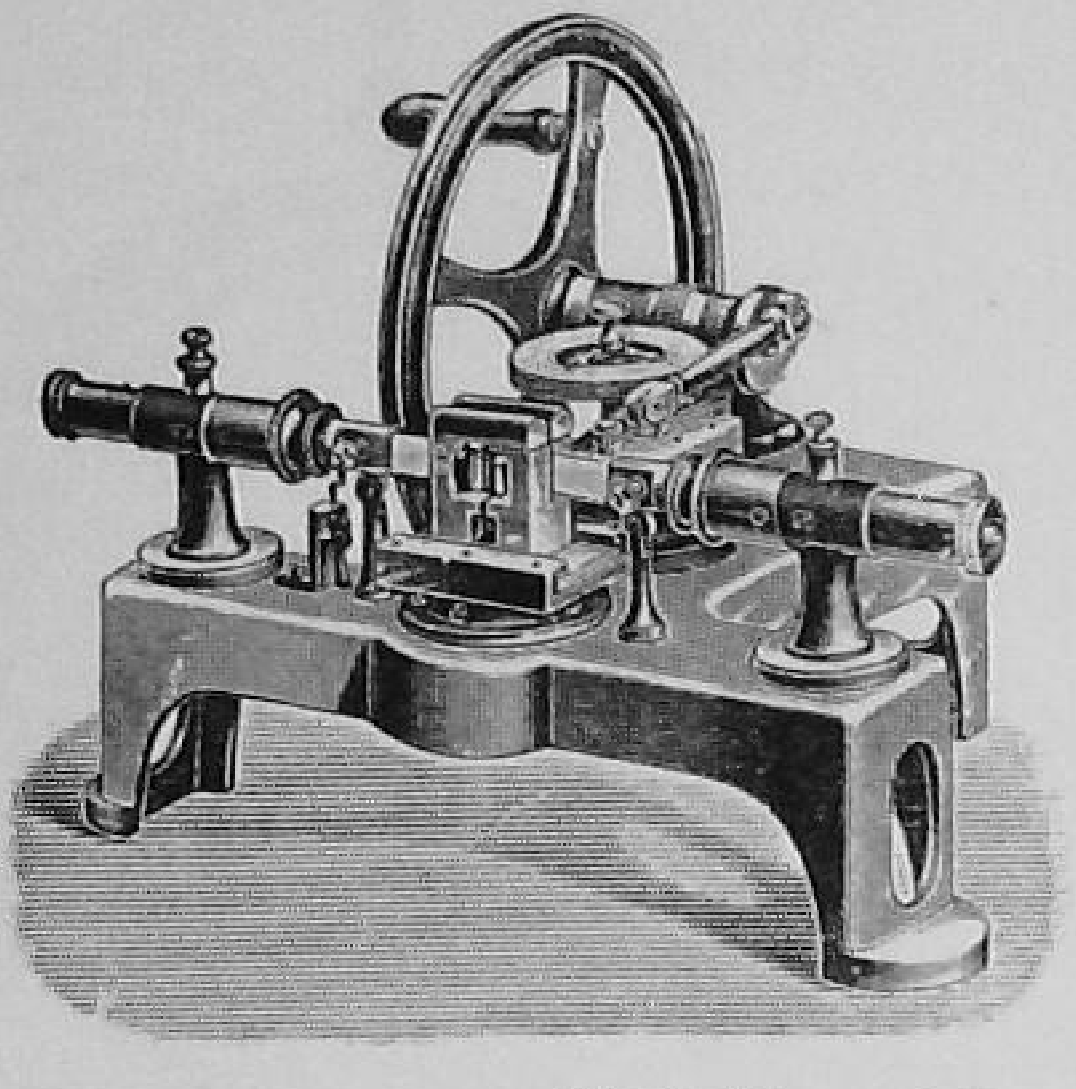
The more recent motor-driven instruments of this type, by Goodbrand—illustrated in Fig. 229—have a two-speed gear box giving alternative loading rates, and a graphic recorder indicating the stress/strain diagram of the paper specimen examined. When using these machines which require a strip, it will be found that strips cut in the machine direction have a greater tensile strength than those cut across the web. Hand-made papers show little difference owing to the shake being applied in both directions during making. While the Mullen and Schopper types do not show results in any relation to each other, it will be found in practice that either machine will bear out the evidence of the other.

Folding.—Closely allied to the question of strength is that of 'folding'. Envelope papers, paper for bags, etc., require to be capable of being folded without danger of the paper breaking at the hinges and folds.

Folding Endurance.—The most widely used instrument for the determination of folding endurance is that by Schopper (Fig. 230). A strip of paper cut to a standard template is clamped under a known arbitrary tension and subjected to a continuous backward and forward folding effect. This folding effect is produced by a slotted steel plate, which through a reciprocating motion folds the strip until fracture takes place. The number of folds required to produce fracture is recorded on a dial, the operating mechanism of which stops at the time of breakdown. The number of folds that a given paper will stand before fracture occurs under a given tension offers a fair indication of its cohesive properties. It is essential that the folding endurance test is carried out in a constant humidity room, since this test is very susceptible to change in atmospheric conditions. A folding endurance carried out at 70 per cent relative humidity may be double the value obtained on the same sample conditioned and tested at 60 per cent relative humidity.

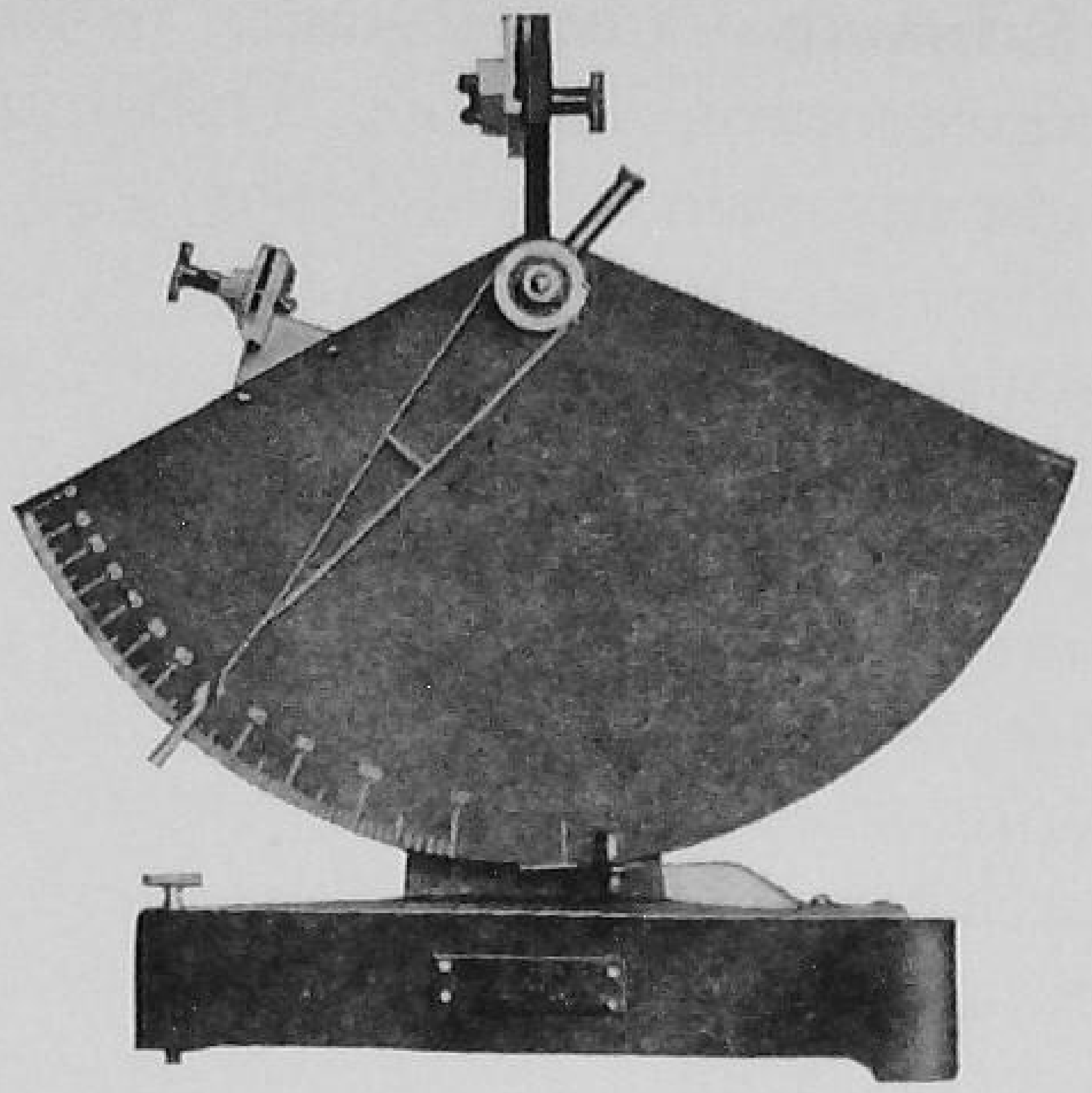
Tearing Strength.—It has been claimed that the tearing strength is a better criterion of paper strength value for practical purposes than either the tensile or bursting strength. A popular instrument for the measurement of

tearing strength is the Marx-Elmendorf (Fig. 231). A specimen of paper is accurately cut to a template in such a manner that two parallel slits form a



[H. E. Messmer Ltd.

FIG. 230.—FOLDING TESTER



[Masson Scott & Co. Ltd.

FIG. 231.—ELMENDORF TEARING TESTER

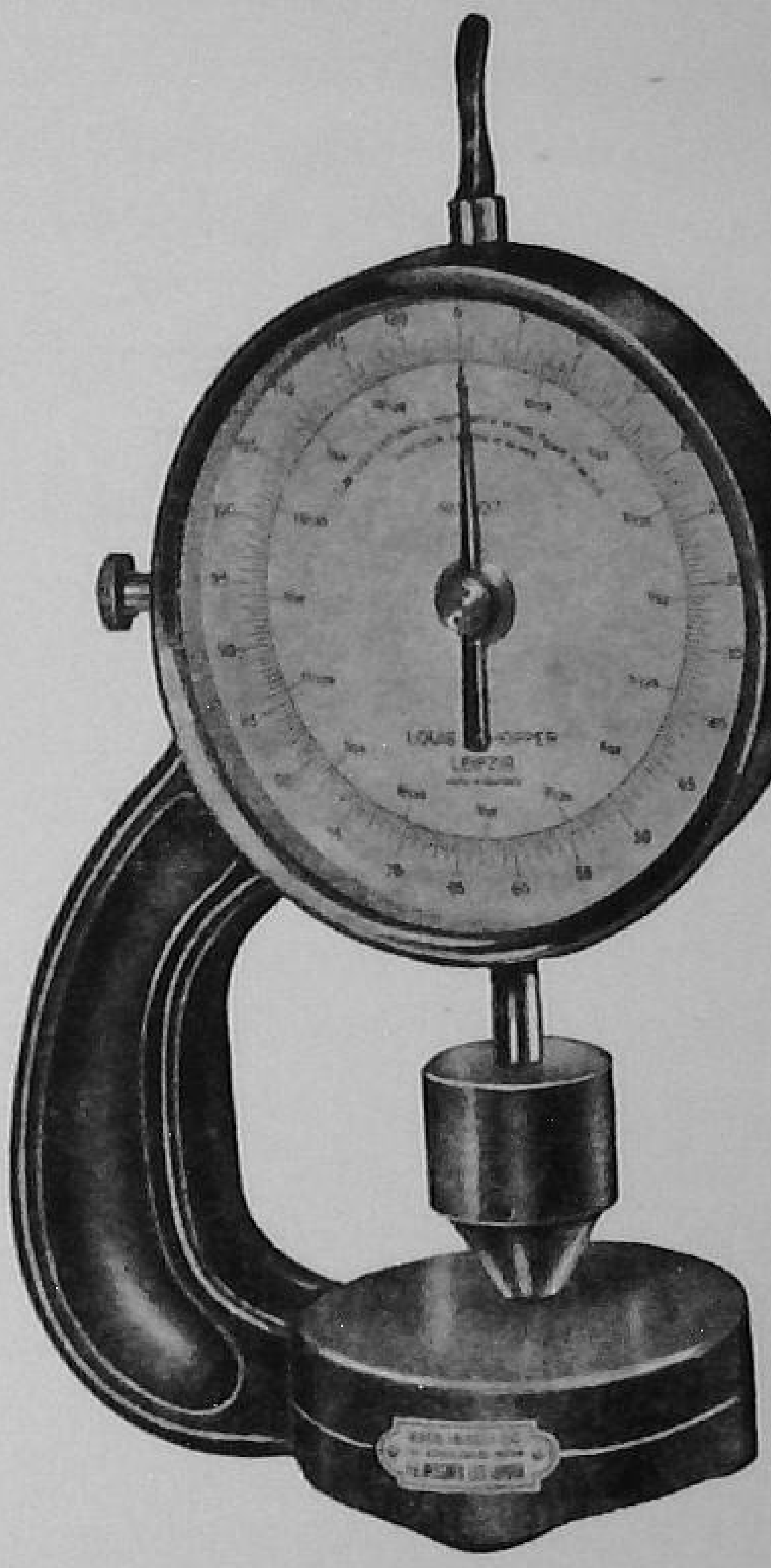
centre tongue, the equivalent of the start of a double tear. The outer tongues produced by this cutting are held in a fixed clamp, while the centre tongue is subjected to the load of a pendulum to continue the tear. The load necessary to continue the tear is recorded through a spring-loaded friction pointer on the scale forming the pendulum. Thus the instrument records the work done in continuing a tear in a given length of paper, and not the resistance of the paper to the starting of a tear. The magnitude of the tearing force as determined above is very small compared with the breaking load under tensile stress for the same sheet of paper. Like the tensile strength, it is possible to determine the relative tearing strength in both 'machine' and 'cross' directions, a factor offering some indication of fibre orientation in the sheet.

Thickness.—The thickness or 'bulk' of paper is measured by small instruments known as micrometers (Fig. 232). These are very delicate instruments graduated to thousandths of an inch, and they work either by spring pressure, which is always constant, or by means of a fine screw, the head of which is fitted with a friction arrangement, so that when the face of the screw presses the paper against the fixed face the screw cannot be turned further, and so the paper is not squeezed.

The spring micrometers have a dial, divided into thousandths of an inch, and a pointer shows the thickness of the paper under test.

It is usual to place four or more pieces of paper in the tester at a time, for in this way the ever-present irregularities in the surface of the paper are taken

into account, and it is obvious that this is necessary if the thickness of the paper is required to give any indication of the bulk of a book, etc.



[H. E. Messmer Ltd.

Fig. 232.—Micrometer Thickness Tester

Substance.—The substance, or weight per given area, or more commonly the weight per ream of a definite number of sheets, is ascertained by means of a pair of scales and weights. The paper is cut to the required size, such as 20 × 30 inches (double crown), $17\frac{1}{2} \times 22\frac{1}{2}$ inches (demy), $16\frac{1}{2} \times 21$ inches (large post), and a sheet of this size is weighed, either by a balance scale and special weights, or in a special lever scale, which has a graduated quadrant plate, on which is engraved the weight per ream of 480, 500 or 516 sheets. In these latter scales a sample sheet of any desired size may be weighed, so that it is an extremely useful instrument for the machineman to have on his table, enabling him, as it does, to cut a sheet of the exact size of the finished paper and weigh it, thus avoiding the necessity of calculating the weight in the usual mill standard size, such as double crown, etc.

It is usual in mills making paper of many distinct sizes and substances to have metal templates for all the more usual sizes, so that the machineman may quickly cut out a sheet for checking his weight.

Air Permeability.—The permeability of a paper to air is a guide to the degree of calendering, coating, sizing or beating. The two most popular instruments for this determination are the Potts permeability apparatus and the Gurley densometer. The former is readily constructed from simple laboratory materials, and has the advantage over the Gurley instrument in that the determination is made at constant pressure. The sample of paper is held in a clamp of known dimensions and air is drawn through the sheet under constant pressure by means of a water aspirator fitted with a Marriotte tube. By measurement of the volume of water passing from the aspirator in a given time it is possible to report the air permeability of the paper as volume per unit time for air passing at a given pressure through a known area. A

mathematical interpretation of the significance of observations by this apparatus has been given.

The Gurley densometer operates by allowing a cylinder of specified characteristics, having a specimen of paper to seal its upper end, to fall freely in a second cylinder containing oil. The paper is clamped between two orifice plates having an opening of 1 square inch, and the inner cylinder is timed for a given fall equivalent to a known volume of air being displaced through the paper at the upper end. The permeability is then reported as the time taken for the displacement of 100 c.c. of air. An improved type of this instrument is now available in which the inner cylinder is sealed at the top and air is forced through an inner tube extending to a paper clamp at the base of the instrument. It will be noted that the Gurley densometer does not permit the passage of air through the paper specimen at constant pressure.

The Gurley smoothness tester is a development of the densometer. By this device both sides of the sheet are subjected to an equal air pressure by the equivalent of a densometer falling cylinder. The paper is supported between two optical flat steel blocks with a centre opening connected to the falling cylinders, so that the passage of air is outwards between the face of the sheet and the steel block. The rate of flow of air across the sheet is determined by inequalities in its surface, and so is a measure of smoothness and 'finish'.

The degree of sizing of paper is usually measured by the rate of water penetration. By means of the Currier apparatus the time is determined in which a sample of paper is penetrated by water, the sample being placed on a metal plate and covered with a wet felt. Liquid penetration has been followed by a change in the light reflection on the upper surface of a paper sheet due to a liquid penetrating from the under side, the reflection being followed photo-electrically.

Of interest to the printer is the softness or compressibility of paper. The Bekk hardness tester is used for observations on this property. The instrument consists of a metal cylinder with a spherical end attached to a rod and free to move in a vertical plane like a pendulum. The paper sample is clamped against a hard steel plate vertically below the pivot of the rod. The metal cylinder is withdrawn through a standard arc and after lightly inking the spherical end is allowed to impinge on the paper sample. The area of the ink spot produced on the paper is a measure of its compressibility. The rebound arc of the cylinder is also measured, since this affords an indication as to whether the paper will be permanently deformed and embossed, after printing. A paper with a small rebound arc, and therefore low elasticity, may be permanently indented during printing.

Another attempt at deriving a numerical measure of a rather obscure paper property is afforded by the Bekk resistance to 'picking' apparatus. 'Picking' is a difficulty experienced on printing machines where small surface areas of paper become detached and adhere to the printing rolls. It is claimed that this apparatus indicates the relative freedom from 'picking' in different papers. While the apparatus may give a broad indication as to the relative merits of different papers, the conditions of the test are not strictly comparable with those encountered in practice on a printing machine.

An instrument is offered by Schopper to measure the ink-absorption properties of blotting papers. The same manufacturer is also putting out a continuous bending tester which it is claimed has overcome some of the fundamental failures in the design of the folding endurance tester.

During recent years the optical properties of paper have received much attention, and at the moment quite a number of instruments are marketed to determine both the opacity and gloss of paper. The use of some of these instruments is restricted to the routine checking of batches of similar papers and do not give reliable observations on papers of widely different characteristics. In the main their operation depends on the measurement of the amount of light from a standard source passing through the sheet (for opacity) or reflected from its surface (for gloss) through the medium of a photo-electric cell. The choice of the photo-electric cell is important, it being essential to use a cell system with the same colour response as the average human eye. Amongst the more popular instruments for this purpose are the Westinghouse Trans-O-Meter, the Bausch and Lomb Opacimeter and more recently the Lange reflection meter. A very high sensitivity in the measurement of whiteness is claimed for the Leukometer (Zeiss).

Composition.—A knowledge of the nature of fibrous materials of which a sample is composed is of very great importance to the paper-maker. On that knowledge the price is estimated; without it he may make serious mistakes.

Suppose, for instance, a sample is submitted and a price agreed on to match it in all respects. The paper offered may be all right in all details, but may contain a fibre that the customer does not want, and is not in his sample. He would be quite justified in rejecting the making. It is not at all unusual for papers containing wood fibres to be offered as matches to 'all-rag' samples either through ignorance or a desire to make a little more profit, or to get the order at a 'cut' price.

The microscope is a very necessary piece of apparatus in the identification of the constituent fibres of the paper furnish, and useful work may be performed with relatively simple apparatus. We have already (see Chapter II) indicated the chief points of difference in the various fibres, and

little difficulty should be encountered in recognizing them. The paper specimen is disintegrated and stained for examination, the Hersberg stain probably having the most wide application. Whilst different fibres assume a different tint by the stain, this characteristic tint is not the true medium of differentiation, the function of the stain being to exaggerate the characteristic appearance of the fibre. A table of colour reactions on fibres by the more commonly used stains is given in the Appendix. Furnish may be approximately estimated by a count of the different fibres present, although beating adds to the difficulty of such an estimation.

Transparency and Opacity.—Transparency in paper depends on the comparative absence of light-reflecting or-absorbing faces or facets in or on the fibres, minerals or other items of its composition. Any treatment—parchmentizing, waxing, finishing, fibrillation or the addition of such substances as size, starch, etc.—which tends to cause the fibres to pack closely together and eliminate or fill up air space produces transparency by allowing light rays to pass through the sheet more or less unbroken or unreflected.

For example, vegetable parchment before and after treatment. This paper is beaten free and consequently is very opaque, but after the manufacture is completed it is the reverse. Blotting has its opacity from its bulk, which is the result of quick and free beating with very sharp tackle, and the softness and want of felting qualities given to the cotton fibres by treatment. Yet the same furnish may be treated to produce a comparatively transparent sheet, if highly fibrillated, sized and finished as a writing paper.

Envelopes to match must be opaque. To get this result the fibres must be beaten long and free and, if possible, china clay and a lower quality of fibre may be utilized.

The second press should not be used; this omission will give a little more bulk and leave the under side of the sheet with a rough surface. All fillers and colours of a mineral or pulpy character produce opacity. So also do all dyes when used to get a deep shade, but a slight addition of a good blue dye will give an increased transparency to paper. A poor or cheap colour always gives a more opaque result than a good colour, owing to the greater quantity required to produce a similar shade.

The transparency of paper generally is a good indication of the quality; the better the quality the more transparent will the sheet appear, owing to the greater care that has been taken in boiling and bleaching the fibres, and the purity of the colour, size, etc. A finish given on the machine with iron rolls gives a more transparent paper than the super-calender or plate glaze, owing to the greater compression and loss of bulk. The colour and quality of water used at the mill influence the transparency of the paper, so that one mill will

have difficulty in giving the opacity, and another the transparency or purity.

In the first case the stock may be dulled down with a touch of nitrate of iron, and brought up to the colour with blue and pink; in the second, it may be necessary to use a higher grade of stock and to touch up the shade with dye.

Opacity Measurement.—The opacity of paper is of importance in many fields of use, and the measurement of paper opacity has received some attention. A thorough examination of the optical properties of paper has been made by V. G. W. Harrison, to whom excellent published reviews are due.

A number of photo-electric instruments claiming to measure opacity have made their appearance. In general these instruments measure opacity indirectly in terms of contrast ratio, or the ratio of the brightness of paper backed with a dead black compared with the brightness of the paper backed with a standard white. The T.A.P.P.I. method follows these lines, and suggests the use of magnesium oxide as a standard white backing and a black cavity as its comparison. Typical instruments making opacity measurements by the contrast ratio method are the Bausch and Lomb Opacimeter and the Photovolt Reflection Meter. The Photovolt instrument has a portable 'search unit' which consists of the light source and the operative photo-cell.

An ingenious method for the direct measurement of opacity by transmission has been devised by C. F. Sharman, who modified a Spekker Absorptiometer for the purpose. By arranging a paper carrier with two equal openings, one clear and the other covered with the test piece, to cover one cell of the Spekker, it is possible to determine the light absorption effected by the paper and to report the 'percentage transmission.'

The Durability and Storage of Paper.—In the hurry of modern paper-making the durability of paper is a subject that few paper-makers seem to consider. A hundred years ago paper-making was a slow, not to say leisurely, process, when the result of the paper-makers' labour was a thing to be prized and taken care of. Books were carefully bound and treasured as lasting records, and from first to last the art of paper-making and book-binding was conducted with the object of producing an enduring article.

With the advent of machinery this ideal began to change, not because of the greater output that became possible, but because progress demanded that output. The slow, old-fashioned methods and materials were too expensive, and other methods, quicker, cheaper, with more abundant materials, became necessary if paper-making was to keep up with the advance of science and

the general progress of the world. This inevitably meant poorer and less durable products, but it was recognized that these were quite good enough for what was required of them. Now this idea has developed so far that no one troubles about paper further than that it will fulfil the purpose of the moment, and that it can be obtained at the lowest possible price consistent with that condition. The paper-maker is now compelled to supply demands on that basis, and when we have complaints from printers and stationers about the paper they receive, we feel tempted to reply that they are getting no more and no less than they are paying for.

Any of our 'fine' mills can supply a paper that will last under ordinary conditions, for ever, but very few printers, for instance, would be willing to pay a price that would enable the paper-maker to make that paper. The object of the paper-maker is to supply the best he can for the price, and this best too often falls short of the quality he would prefer to give. There are, however, papers that are admittedly made for the moment. They serve the purpose and are discarded. The principal paper of this class is newsprint. All papers containing mechanical wood are short-lived. The resin and natural impurities in the wood very quickly bring about the destruction of the paper, which turns brownish-yellow in colour, grows brittle and ultimately is reduced to dust. Newsprint does not work well on the printing machine when newly made. It is all the better for standing a few weeks to absorb the normal humidity of the atmosphere, and to allow any electric charges to pass away. But within 10 years after being used, newsprint generally is so much deteriorated that it can scarcely be handled. It may be preserved by pasting a thin tissue of good quality over it, but it is doubtful how long a newspaper will be readable even with this plan.

On the other hand, news-sheets printed 100 years ago on hand-made rag printing paper are as good as ever. One of the greatest factors in the deterioration of paper is the use of resin size. Resin, when exposed to light and air, becomes friable and is reduced to dust, and all papers sized with resin lose their ink resistance, colour, strength and finish. When resin size is supplemented by a coating of gelatine the life of the paper is lengthened, by how long we cannot tell yet; but it is certain it will not in 100 years be in the same perfect preservation as when it was made, or as the hand-made papers of a century ago are at the present day. By substituting silicate of soda for resin we get a much more durable and light-resisting paper, such as may be used for printing with printer's ink.

As regards dyes, many cannot stand light at all without fading out and taking all the good of the paper with them. The aniline or coal-tar products are mostly of this class. Smalts blue is, of course, a permanent colour, so also

in a great measure is good ultramarine blue and most of the mineral colours, except those which owe their shades to oxides of iron, and which tend to go darker in colour and destroy the cellulose. Chemical residues of alkalis, bleach, acids and possible combinations of chemical traces in mill water may cause or hasten deterioration of paper. A very curious effect is produced by age in the particles of copper or brass that are found in a great many good papers that have been beaten with bronze roll bars, or that have been made from rags in which pieces of copper have been retained. In a few years, from each of these particles irregular lines spread outwards through the fibres, sometimes covering a space $\frac{1}{4}$ inch in diameter. These are called 'dendritic growths'. The products of the oxidation of the metal travel along the fibres and form fern-like designs.

While the paper-maker knows that many of his products are more or less perishable, he is also aware that some or all can be greatly improved by being kept in stock for varying lengths of time, under proper conditions, before being sent out from the mill. All machine-made papers are produced under a certain amount of strain, and the fibres ought to get time to relax. Most printing papers are improved by being kept in a cool, dimly-lighted stock room for a few weeks. Papers intended for litho work especially will benefit by absorbing atmospheric moisture and getting rid of their electric charge. On gaining a normal air-dry condition finish goes off more or less. A plate-glazed finish is most permanent; next in order is a super-calender finish. Any glaze or finish obtained by hot rolls is most liable to go back. But a wise paper-maker provides for this by having the finish a little higher than the sample in the first place. Complaints are often made of deficient bulk and too high finish when all that is required is a reasonable time for paper to mature. For this reason it is bad policy for a customer to send an order and ask for *immediate* delivery, unless he knows the mill stocks the paper he wants, and also for the paper-maker to delay making an order until he has to send it out as soon as it is made.

Poor quality or badly-made gelatine size is also a common cause of the deterioration of paper. Given the least extra humidity in the stock room, poor size begins to give off an offensive odour, and the paper loses strength, colour, finish and ink resistance. Generally a good quality of gelatine size, properly made, will withstand the ordinary variations of humidity in the stock room, but any definite dampness continued for a time produces bacteria which destroy the gelatine.

Paper should not be stocked on a ground floor or under ground level, where the atmosphere is likely to be humid. A well-ventilated stock room on the second floor is most desirable, with a temperature of 60° F. and a diffused

light from ground-glass windows, preferably greenish-tinted. All ventilators should be covered with wire cloth, to prevent dust or sooty particles from gaining admission, and no machinery or shafting should be installed in a paper store.

Sweeping can be safely undertaken by putting down damp sawdust, to which the floor dust will adhere, or by using a vacuum cleaner. Spraying the floor with water before sweeping makes the air too moist, besides the risk of splashes or drops of water getting on the stacks of paper. Even under the strictest conditions there will be some dust, therefore a sheet of wrapping paper must be used to top each pile of paper or packages, and sheets of wrapping put on the floor for the stacks to stand on, the sides being tucked in all round to a height of 6 or 8 inches above the floor level. Wide avenues should be left between each double row of stacks, so that every stack can be reached without disturbing another. All those who have to handle the stock must have clean aprons or overalls and must keep their hands perfectly clean. It is surprising how many sheets a dirty thumb will spoil. The stacks ought to be built up carefully so that there are no protruding sheets, which will certainly be broken at the edges when the paper is again lifted. The height of the stacks will depend on the size of the sheets. A small sheet will not stack safely to any great height, especially if it has a low finish, as a slight push may send it over. A safe rule is that no stack must be higher than a man of average height can build without the use of steps. If the paper is in wrappers there is, of course, less danger of it being spoiled in the stack. It is not advisable to use gas lighting in the stock rooms; apart from the risk of fire, the products of the combustion of gas have a deleterious effect on paper.

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CHAPTER XXVI

WATER TREATMENT: RECOVERY AND RE-USE OF WATER

REMEMBERING that water is the 'raw material' of paper-making consumed in the greatest bulk, its quality is of obvious importance. The actual quantities of water consumed, for the different classes of paper made, vary widely. In the production of rag paper the demand may rise as high as 150,000 gallons per ton of paper, whereas newsprint production may only consume 2,000 gallons per ton of paper.

It is only to be expected that most water supplies will require some form of treatment according to the quality of the paper made. Generally, water has to be treated to remove suspended matter giving rise to turbidity, colour and dissolved solids, especially calcium and magnesium salts, which constitute 'hardness' and in some cases iron and manganese. The ultimate treated water should be bright, clear and sterile. Some mills have, by their site, the fortunate provision of some storage space for the raw water. Such storage allows for a preliminary sedimentation of the larger particles of suspended matter as well as a desirable balancing effect minimizing what would otherwise be abrupt changes in quality.

The greater number of mills, usually sited on a river, are denied this advantage.

Although preliminary settlement allows for the deposition of gross particles of suspended matter it has no appreciable effect on the general turbidity of the water, nor its colour. Turbidity can sometimes be satisfactorily removed by simple filtration, though in the main it is of advantage to pre-treat the water by a process of coagulation and flocculation. Coagulation consists of producing a bulky precipitate of aluminium or iron hydroxides in the water which trap the finer colloidal impurities and form them into a coarse flocculated coagulum. The formation of the 'floc' is accelerated by a gentle motion of the water mass until the coarse coagulum is sufficiently bulky to be deposited as an easily removable sludge.

Alum (or sometimes sodium aluminate) is the most widely used coagulant and is applied either as a solution or by a 'dry feeder' in doses from 5 to 50 parts per million. For the best use of alum some measure of pH control is necessary, and it is found that the most stable floc is formed around pH6.

More recently silica has been introduced into the coagulation process

as 'activated silica', formed by the controlled neutralization of sodium silicate with sulphuric acid. The value of activated silica in conjunction with alum is in its power to widen the range of pH through which efficient coagulation can take place and also in producing a mechanically stronger and heavier 'floc'. The heavier 'floc' settles more readily from the water bulk with a consequent reduction in treatment space.

The handling of the water after treatment with a coagulant must necessarily avoid turbulence or the part-formed 'floc' will be broken down and redispersed. The shape of the treatment tanks has therefore received attention and more recently 'accelator' or 'precipator' tanks have been evolved. The tanks endeavour to promote optimum 'floc'-forming conditions with a consequent saving in plant size. Final clarification of the water is effected by filtration, usually through a graded bed of sand. 'Slow sand filters', which were only able to treat lightly contaminated water, have been replaced by 'rapid sand filters'. As the name implies, the slow filter can only pass a relatively small volume of water, something like 2 gallons per hour per square foot of filter area. On the other hand, the rapid sand filter, which is either an open gravity filter or a closed pressure vessel, will pass something like 100 gallons per hour per square foot. As would be expected from the greater throughput, the rapid filter requires much more frequent 'washing back' for the removal of the retained solid matter in the filter medium.

The pressure type rapid filter, which is essentially a cylindrical steel vessel 8 or 9 feet diameter containing the filter medium, is used in conditions where it is necessary to maintain a hydraulic gradient. It is obvious that the advantage of available pressure would in some circumstances be lost if an open rapid gravity sand filter were used on the same site. The open gravity filter, however, has a pronounced advantage in that the state of the filter medium is always available to observation. Both types of rapid filter are cleaned by 'washing back', the process being further improved by scouring the filter bed with an air stream, or, as in the case of some pressure filters, by the provision of a mechanical stirrer.

Water treated by the above processes, although freed from turbidity and colour, has undergone little or no change in its dissolved solids. It is often necessary to treat 'hard' water containing appreciable calcium or magnesium for use in, say, steam raising. The 'lime-soda process' is widely used for this purpose, whereby calcium and magnesium bicarbonates are precipitated as their carbonates with lime and the corresponding sulphates and chlorides are similarly precipitated with soda. The relative proportion of lime and soda used depends on the bicarbonate ('temporary') or the

sulphate and chloride ('permanent') hardness of the water. The process is often carried out in cylindrical tanks which allow for the sedimentation of the precipitated carbonates and their collection and removal from a conical base.

It is not unusual in the case of hard water to find the lime-soda process used prior to water softening by a 'Zeolite' process. Certain hydrated complex silicates have the power of 'base exchange', or they are capable of replacing calcium with sodium from their structure. In this manner a vessel in the form of a pressure filter, if filled with a granular sand-like bed of a zeolite, will soften hard water pumped through it by its power of replacing the calcium in the water with sodium. When the bed is exhausted and all its sodium has been replaced by calcium it may be recharged by 'washing back' with a strong solution of brine whereby all the retained calcium is replaced by sodium from the salt, and the softening cycle can continue. Zeolites now used are synthetic preparations.

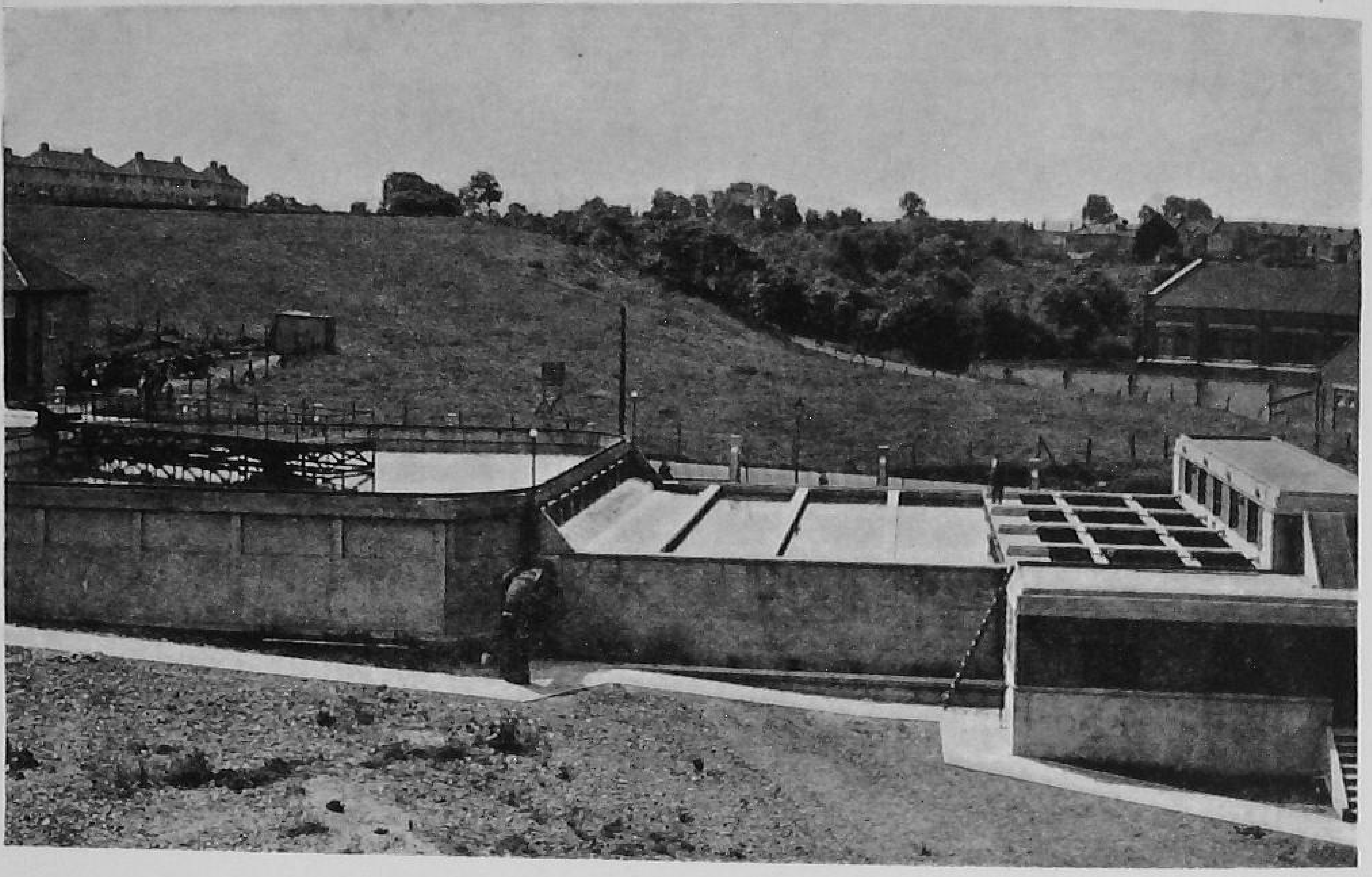
Water used for boiler feed purposes, especially in high pressure boilers, is often treated with sodium phosphate finally to precipitate and remove calcium as its phosphate. It is also 'de-aerated' to eliminate the corrosive effect of dissolved oxygen by flash boiling under vacuum in a 'De-aerator'. Final traces of dissolved oxygen may be removed by the treatment of the water with sodium sulphite.

For general process work the advantage of a sterile water in minimizing the formation of slime-like growths in the water storage and piping system is apparent. Sterilization is conveniently effected by dosing the filtered water with about 0·5 parts per million of chlorine.

An example of the gravity sand filter is that made by the Paterson Engineering Company, and illustrated in Fig. 233. In this type of filter the water is treated as it enters the plant through a dosing machine with whatever chemicals are necessary for the particular water. The dosing precipitates and coagulates the deleterious matter which is then more easily filtered out on the sand bed of the filter. It is usually necessary, unless very big storage is available, to have two treatment tanks, in order that one may be put out of action and washed back for cleaning the bed and running to waste the matter which has been kept back on the sand. These filters give most excellent results, and are very easily maintained and operated.

The second type of filter which is in use in very many paper-mills is the pressure type such as that made by Bells, Royles and other engineering companies. In this case there is an enclosed tank as illustrated in Fig. 234, the bottom of which is filled with a large number of nozzles with slits in them, which keep back a predetermined size of sand; the rest of the filter

is filled with sand of suitable size to remove the objectionable matter from the water. The water then passes through the slits in the nozzles, and into storage



[Paterson Engineering Co. Ltd.

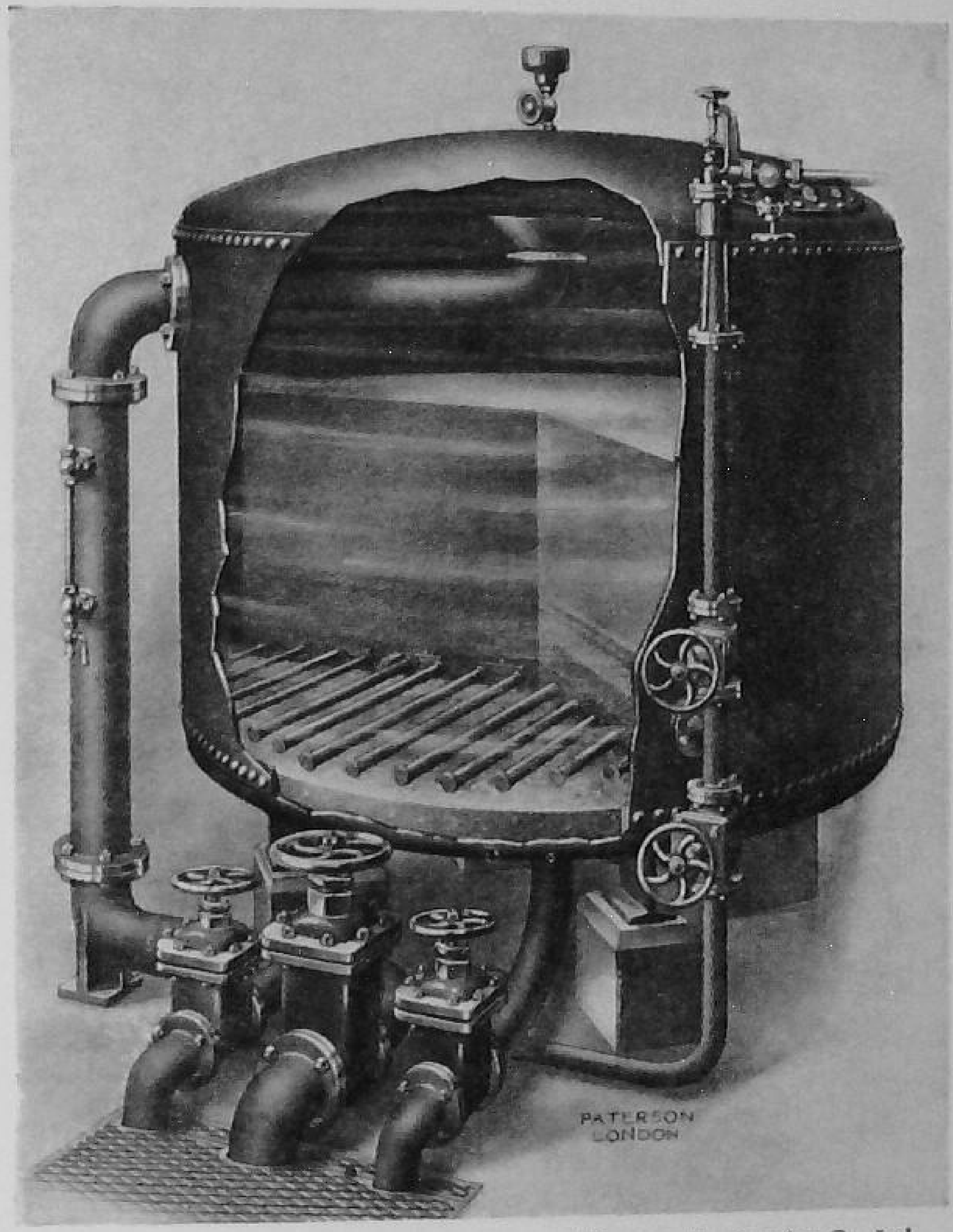
FIG. 233.—WATER CLARIFICATION AND FILTRATION PLANT AT A PAPER-MILL

tanks or direct to the mill. It will be realized that sand of a smaller diameter than the width of the slits will also pass through with the water, and may have to be settled out by gravity in a storage tank, or the water, after passing through the pressure filter, may be passed through a revolving drum with a very fine wire mesh to keep back the fine particles of sand which pass through the slits in the nozzles. Arrangements have to be made for water to be pumped back through the filter at intervals to wash the sand and wash away the dirt which has been trapped by the sand. While this operation is going on it is sometimes necessary to agitate the sand by stirrers, in order to free the dirt from the sand and get it quite clean again before that particular filter is put back again into use. These filters pass about 5,000 gallons an hour, so they are generally installed in batteries to give the total amount of water required by the mill at any one time, with one or two spares to look after the washing-out period.

Dosage tanks usually form part of the equipment for filtering water when pressure filters are used, in order that chemicals may be added to the

water when necessary to precipitate and coagulate the matter which it is desired to filter out.

As mentioned above, when hard water has to be used for steam raising

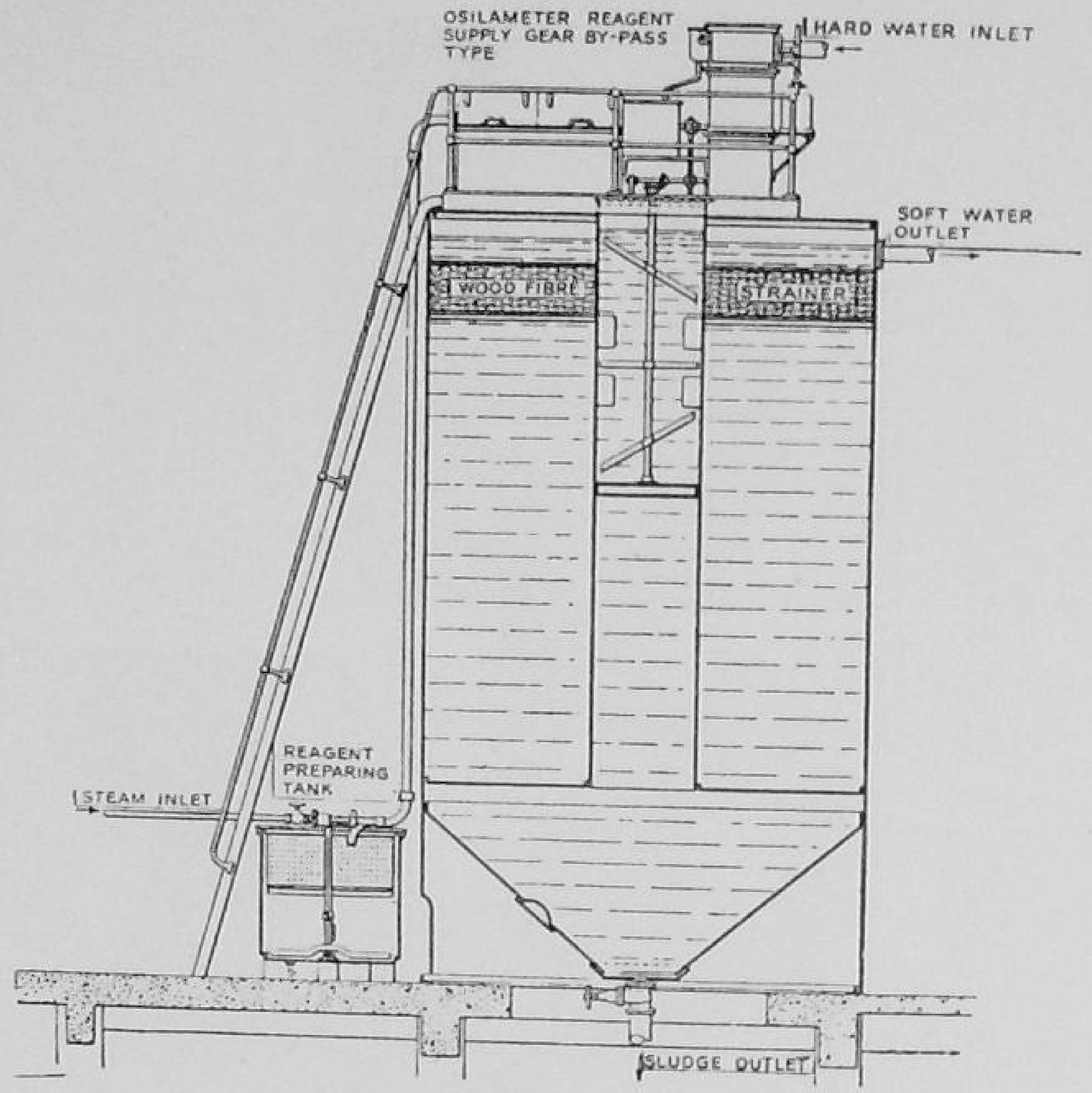


[*Paterson Engineering Co. Ltd.*

FIG. 234.—SECTION OF PRESSURE FILTER, SHOWING UNDER-DRAINING SYSTEM

in the mill, it may first have to be softened, in order to prevent scale in the boilers and economizer pipes. There are several plants made for this purpose, such as the Kennicot and the Paterson water-softening plant. The Paterson consists of a tower (Fig. 235) at the top of which is a mixing tank for chemicals and also the intake for untreated water. The water flows down a central tube fixed in the middle of the tower, and is mixed with the softening chemicals as it passes down. When the water reaches the bottom of the tube, it passes up the tower again, depositing any heavy insoluble matter at the bottom, which can be drawn off. On reaching the top, the water passes through a filter where any suspended matter is removed, and it is now

softened and cleaned ready to pass to the boiler feed tank. The system is effective and simple in operation, and costs very little to run. The treatment which boiler feed water should receive before it enters the economizers



[*Paterson Engineering Co. Ltd.*

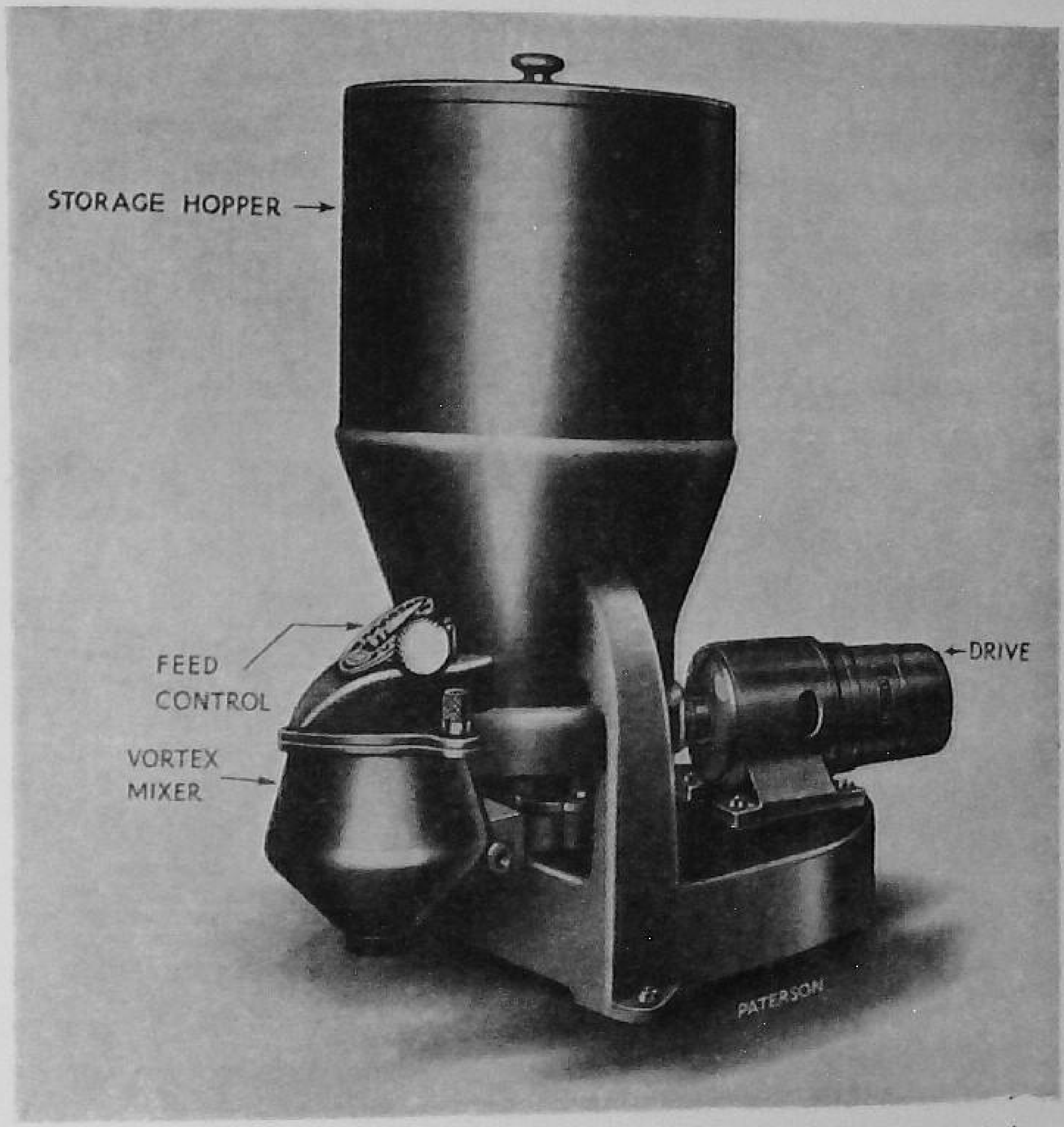
FIG. 235.—TYPICAL VERTICAL WATER SOFTENER, LIME-SODA TYPE

depends, of course, entirely on the nature of the water, and no hard and fast rule can be laid down for water in general. This must be found out by chemical analysis in the first place, and then suitable treatment given to the water.

In choosing a site for a mill too much importance cannot be attached to the question of water supply, and exhaustive tests must be carried out to ascertain the amount and quality of the supply, having due regard to the immediate and possible future requirements.

Some of the filters at present available give excellent results, require little or no attention and are self-cleaning, this latter operation taking only a few minutes each day. They remove all suspended matter and make a wonderful improvement in the quality and brightness of the colour. Brown peat water, often in flood time the colour of beer, comes through the filter quite clear and bright. The same applies to ordinary river water, which may often be

contaminated with road water, surface water from streams and in the summer months with rotting water-weeds.



[Paterson Engineering Co. Ltd.

FIG. 236.—CHEMICAL DRY FEEDER FOR THE ACCURATE ADDITION OF CHEMICALS FOR WATER TREATMENT

THE RECOVERY AND RE-USE OF WASTE WATERS, FIBROUS MATERIAL AND LOADING

In almost all mills a large quantity of fibre and clay may be recovered from the back-waters of the machines. Generally speaking, the lower the grade of paper being made the greater is the amount of stuff which can be recovered. Until quite recently it was common practice for the waste waters containing size, colour, loading and fibres to be run to the drain, river or other convenient place, and thus much valuable material was lost and much pollution of rivers caused. Two factors were chiefly responsible for the curtailment of these losses, one being the increased competition in the trade and consequent need for economical production, the second the

tightening up of by-laws concerning pollution by river conservators and fishery boards.

The yield of material in a rag mill may be taken to be from about 60 to 80 per cent, so that from 100 tons of rags anything from 20 to 40 tons are lost between the rag loft and the machine reel. A good deal of this loss is represented by unsuitable material thrown out, and also by the removal of dust, loadings, starch, grease and ligneous matter during the boiling and bleaching operations. Apart from this, however, there is a serious loss of small fibres during the washing and draining of the stuff, and again at the machine, where a great deal of small fibrous material is washed away through the meshes of the machine wire. There is also a loss at the auxiliary strainer, due to hanks and knots of fibres which get caught here, and are so mixed with dirt, rubber, etc., as to be unfit for further use.

Stuff is also lost which runs down the wire when starting up, or if a break occurs there, and other small losses occur when starting and stopping by stuff going down the pit between the wet felt and second press, and between the second press and cylinder. These latter losses are very small, and may be prevented by the provision of clean wooden boxes to catch the stuff, provided that the stuff is carefully removed at frequent intervals and returned to the beaters in a clean state.

Where the mill makes nothing but fine qualities it will generally be found impossible to use again any of the fibres which may be recovered from the washing waters and the auxiliary strainer. The usual practice in dealing with such waste is to run it to tanks where the fibrous material may settle down, and the clear water is then run off to the river or drain. The tanks are periodically cleaned out and the stuff is thrown away as useless refuse.

If, however, the mill makes its own wrappers from time to time, or has a machine engaged in the manufacture of wrapping papers, it will pay to recover all this fibre in order to assist in making up the furnish of the wrapping papers. This is not only economical, but it also enables a really good wrapper to be made, on account of the rag fibres contained in the refuse.

The method employed to save this material is simple, and consists of running the waste washing water, overflow or cleanings from auxiliary strainers, waste from the wire pit and press pit into large tanks built up of perforated tiles. Here the water drains away, leaving a large proportion of the fibres lying in the bottom of the tank and round the sides. The tanks are periodically cleaned out and the stuff is taken up to the beaters to be furnished for wrappers. The tanks should be of a sufficiently large capacity to deal with all the water from the rag-washing engines, which contains only a small amount of fibre, and they must also be capable of dealing with

the stuff from the machine wire pit when changing or washing up. If this work is being properly and carefully carried out by the machineman the amount of effluent should not be excessive, but there will always be some waste from the bottom of the chest, the sand traps and strainers, and a small amount from the wire pit.

In mills making lower grades of paper the methods employed vary according to the general lay-out of the mill and the grades being manufactured, the amount of waste which has to be dealt with and the capacity of the mill to re-use this waste in lower-grade papers. It may be taken as a general rule that most of the recovered stuff will have to be used in a paper of a lower grade quality or colour from that which produced the waste water.

The most satisfactory method is as follows:

All water from the machine wire pit, press roll pits, wire save-alls and suction boxes should be collected in suitable tanks at the back side of the machine, whence it can be pumped back to any or all of the following places:

1. The machine back-water tank for supplying the mixing box.
2. The beater supply tanks.
3. The machine chests.
4. The sprays at the machine.

When the machine starts up, assuming the back-water service system to be empty, it will be necessary to use fresh water to dilute the stuff coming into the mixing box from the stuff tap, but as soon as the machine has started and the back-water has had time to get round, the fresh water may be shut off and no more will be required. There will thus be a supply of water, containing a little fibre, loading, size, alum and dye, in constant circulation at the machine. The surplus from the save-alls and wire pit over and above the requirements of the machine is then pumped up to large tanks situated above the beaters. From these tanks the beaterman draws his supply for furnishing and emptying the beaters, and for diluting stuff going through the refiners.

When the web is being run down the wire for any length of time, such as that occupied in washing and turning a felt on a news machine, the stuff which collects in the pit is stirred up with water and pumped back direct to the machine chests. This obviates the necessity for shutting off the stuff and possibly upsetting the machine when it is running well. There is a disadvantage in this method—namely, the dilution of the stock in the chest—and the machineman must be careful to see that when he starts up again his weight is not seriously affected.

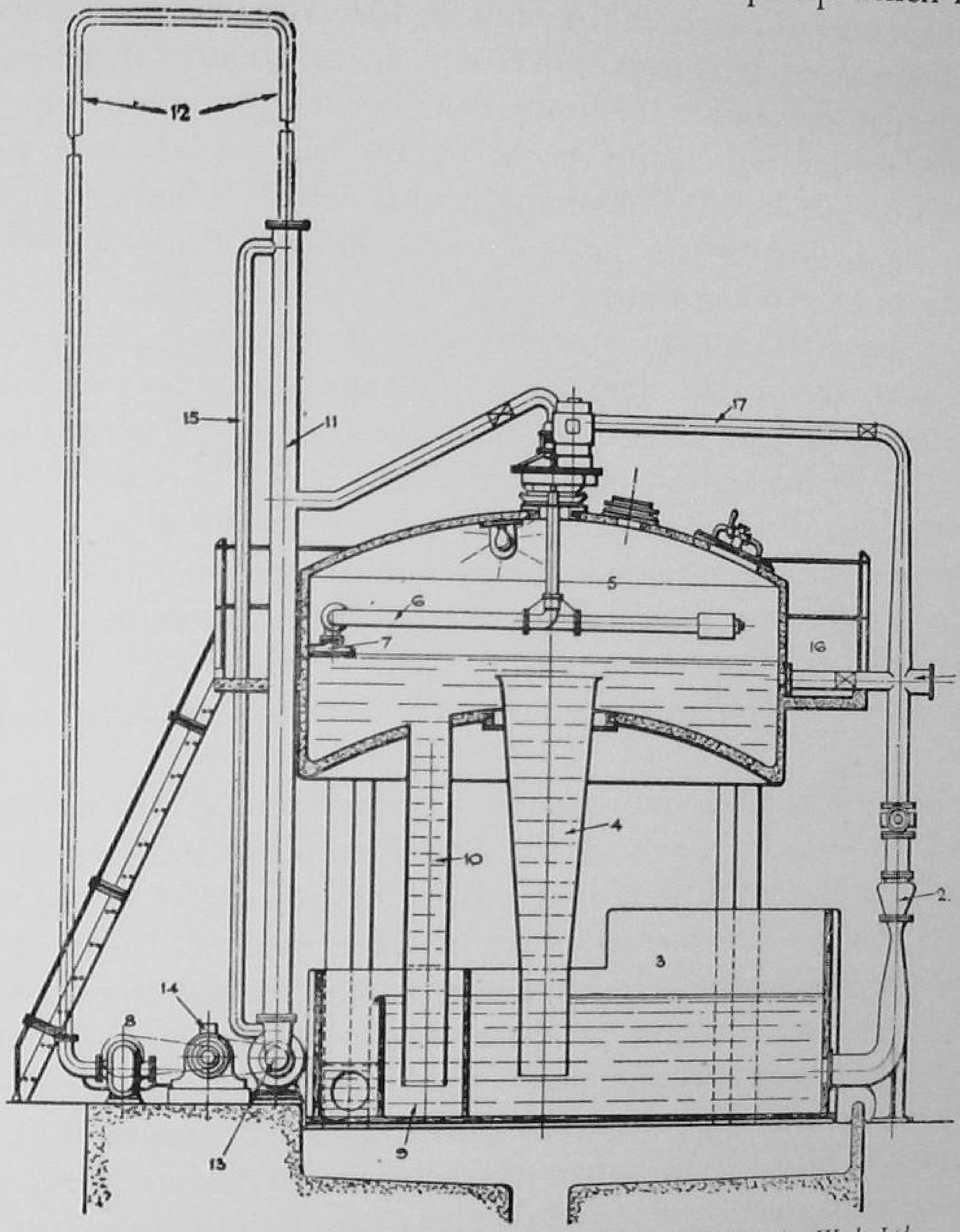
The sprays at the strainers and on the wire rolls may be supplied with back-water, withdrawn from the web at the suction boxes, and thus there is

an economy in the use of fresh water and a consequent diminution in the quantity of back-water to be dealt with subsequently. This water is drawn out at the boxes through the meshes of the wire and has consequently been well strained. It is then collected in a sump and forced by another pump at a high pressure to the strainer and other sprays about the machine. When this method of supplying the sprays can be adopted the use of fresh water is cut down to a minimum, and it will then be necessary only to have a fresh water spray on the breast roll, couch roll and possibly at the breast box to keep down froth.

Adka Save-all (Fig. 237).—This save-all employs the principle of flotation, as opposed to the older forms using the principle of sedimentation. The flotation is brought about by forcing the back-water through a nozzle, designed on the lines of an injector, through which the air is drawn and intimately mixed with the back-water. It is then passed into a chamber, and under vacuum the fibres, surrounded by minute bubbles of air, and flocculated by a suitable flocculating medium, rise to the top of the liquid, where they are drawn off by a scoop, and returned to the paper-machine. The clarified water runs continuously from the bottom and is used whenever desired.

The back-water from the machine is passed through the main inlet (1) and travels down to the aerator nozzle (2), where air is drawn in through the air-intake pipe and intimately mixed with the back-water in the nozzle. It then passes to a wooden box (3); much froth is made in this box owing to the excess air escaping, and the air-intake pipe is led into this froth from a point above the aerator nozzle and keeps it from overflowing. The back-water then flows upwards and back over another wooden partition to the base of the surge-pipe (4), up which it is drawn by the vacuum in the body of the Adka. This vacuum is maintained by the excess air being drawn off through the same rotating scoop (7), which deals with the thick stuff floating to the top. By reason of the vacuum in the chamber (5) the height of the floating stuff in the body is always maintained at the same level, since if the back-water rises above the level of the inlet of the rotating scoop, no more air could be sucked from the body, and in consequence the back-water could not rise any higher; and likewise if the back-water should drop below the level of the scoop, the vacuum would be automatically increased, which would once more draw it up to the right height. In practice the level of the back-water in the body seldom varies more than $\frac{1}{8}$ inch, which is usually insufficient to cause any serious fluctuation. The thick fibre and clay on the top of the back-water in the body is drawn upwards to a separating chamber (11), where the stuff falls to the bottom and is dealt with by a

centrifugal stuff pump (13), and the air rises to the top, where it is drawn off over a barometric column (12) by a drum vacuum pump which is always



[Watford Engineering Works Ltd.

FIG. 237.—THE ADKA PATENT SAVE-ALL

kept submerged by a priming tank set alongside (8). The centrifugal stuff pump should be of sufficient capacity to deal with the stuff drawn off, and be capable of pumping it to wherever desired, in most cases to the sand traps of the paper-machine. The clarified water freed from the clay and fibre travels down a series of pipes (10) set around the base of the body, all flowing into one common outlet pipe into a box (9), from whence it is discharged to the drain or for re-use. The ends of the clarified water-pipe and the surge-pipe should always be completely submerged, otherwise the vacuum in the body will be broken and the whole procedure upset.

It will be readily understood that the time taken for the whole cycle of operations is very much shorter than that in a sedimentation type of save-all, as the back-water is dealt with almost immediately, and it is only a matter of a few minutes to effect changes of colour. In practice, with short delivery pipes to the paper-machine, 5 minutes is sufficient interval when changing to get the new colour to the paper-machine. The clarified water is practically free from fibres and clay, and may be used for all ordinary purposes in the mill.

In almost every mill vast quantities of water can, and should, be recovered for further use. This question is now receiving greater attention than formerly, and it is a most important one. Broadly speaking, the water has to be recovered from the machine and returned to the beaters, or to the stuff box at the machine, but there are other places where a great deal can be recovered.

In the case of a rag mill, which uses more water per ton of paper than other mills, water is first used in the rag boilers; this is irrecoverable, owing to the presence of grease, soluble soaps, lignin, etc., and it must be passed to settling tanks if no convenient sewer is available. It should not, in any case, be returned to the river.

The rag washer uses a large amount of water, and this is not recovered, as it contains traces of the soaps formed in the boiler and also a quantity of rag fluff or fibres, but not sufficient to pollute a river. The rag breakers, where most of the washing is done, also use a very large quantity of water, and this also is not recovered, although if a wrapper machine is run at the mill, some of it can certainly be used with advantage for furnishing the beaters. There is a very large amount of rag fibre lost here, due to the finer fibres passing away through the meshes of the washing drums and the washer screens, and also through the button and sand catchers, where these are fitted. The loss sustained during this operation is serious and deserves more careful attention than it generally receives. It might possibly pay to recover this fibre in a save-all, and some of the water used towards the end of the washing is quite clean enough to use again if water is scarce. This would necessitate the use of large tanks and a pump to return the water to the washer.

Immediately following the washing operation in the breaker comes the bleaching, and this uses more water; where the bleached stock is run into drainers or steeps the liquor from these latter should always be recovered when rags are being bleached, and run into tanks, whence it may be pumped back to the potchers to start the next bleaching operation. It is sometimes possible to use the spent liquor from three potchers to complete the bleaching of the rags in a fourth potcher without the addition of any fresh bleaching

liquor, and this represents a great saving. This can only be done, however, when more than the necessary amount of bleach is being used in the first instance—that is, when hurrying stock through the mill.

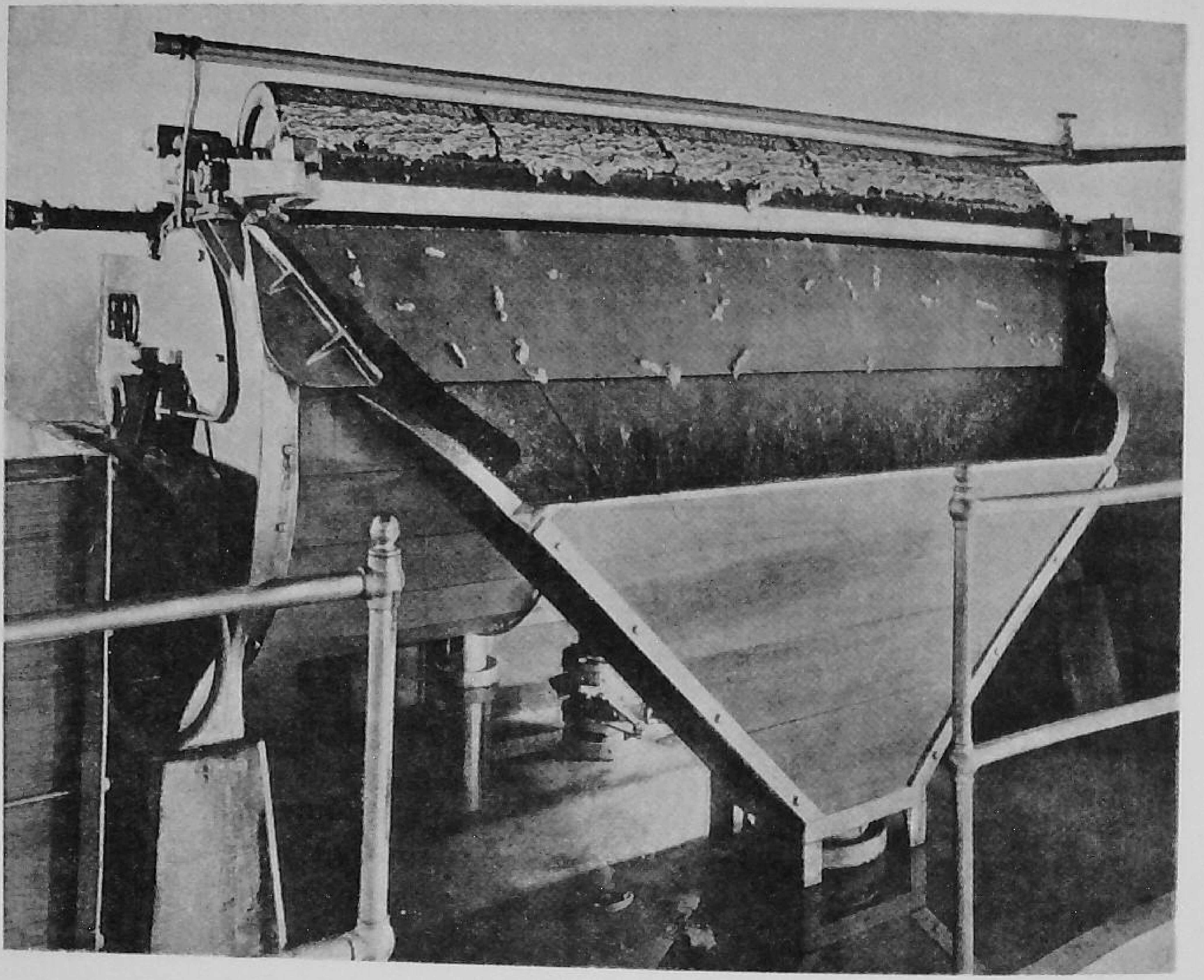
At the machine all spray water from the strainers, water from the save-alls beneath the wire and overflow water from the vacuum boxes should be collected and run to an auxiliary strainer or 'back knotter' and strained free from lumps, knots of fibres and rubber, and then pumped back to the stuff box for diluting the thick stuff from the stuff cock. The careful conservation of all this water represents an enormous saving in chemicals, such as engine size, alum, dyes, loading and small fibres. It also reduces the effluent, which must be disposed of ultimately. It also assists greatly in the reduction of froth and the prevention of scale in the water service system when hard waters are used, and this operation has been proved, when carefully attended to, to double the length of life of the machine wire. In this case, formerly only about half the water required at the stuff box was recovered water, the other half being 'fresh' and very hard. It was found that after a week the machine wire was so filled up with white limy deposit that it was necessary to remove it with a strong solution of vitriol. This, of course, ruined the wire in about 4 to 6 weeks, or even less.

When, however, use was made of all the water which could be recovered, and no fresh water was added, no vitriol was required to clean the wires, and they lasted from 8 to 12 weeks without any special cleaning other than an occasional blow with the force jet. It had also been found expedient to have a spray-pipe on all the wire rolls, whereas after the back-water only was used, no sprays were used except on the wash and breast rolls.

In mills making printings and newsprint there is no recoverable water except at the machines, and every drop of this should be carefully caught and returned to the beaters, stuff box and machine service system, either direct or after passing through some sort of save-all (Fig. 238). This water is generally termed 'white-water', and it comes from the wire and suction boxes at the machine. It is collected in the pit below the machine, and contains large quantities of clay and fibre from the deckle edges which are cut off, and also from the water which passes through the meshes of the wire, carrying clay and fibres with it. The water is kept agitated by means of paddles in the pit, and is pumped to large tanks above the breakers or beaters, whence it is run to the latter when furnishing.

There should be no dirty effluent at all from a news or printing mill, except floor washings, containing oil from bearings, etc., and the only fresh water which should usually be necessary will be for the sprays at the slices and guard board, for the spray damper at the reel end, and for the edge

cutters, and water to make up for that evaporated from the sheet during drying. Other mills making different grades of paper should be able to



[*Vickerys Ltd.*

FIG. 238.—BIRD SAVE-ALL FOR REMOVING FIBRE AND LOADING FROM BACK-WATER OR WHITE-WATER ON THE PAPER-MACHINE

recover varying amounts of water, according to the conditions under which they work, and if it is found impossible to use all the water it should, in any case, be filtered to remove the valuable fibres and clay, which can be used again either in the same paper or in lower grades.

When everything possible has been done to recover the whole of the re-usable water in a mill, in the paper-making process, there will still usually be an effluent of some kind. This varies according to the type of raw materials used and the treatment they receive, and quite a large number of mills are left finally with a very objectionable effluent which usually finds its way into the rivers. New legislation is going to make it very difficult for paper-mills to put this effluent into rivers, and it may be that eventually it will

have to be put into the public sewer, as is in fact done in a few cases at the present time. This becomes a very expensive business, because if it has to be treated at the sewage works of the local authority, they require to be paid for the service, which adds considerably to the costs of making the paper.

In order to reduce this effluent to the minimum, it may be necessary to separate the surface water from waste waters from the various processes in the mill, and keep them separate so that eventually only the most highly objectionable effluent, which is difficult or impossible for the mill to treat themselves, finds its way to the sewer. Where rags and raw fibres such as straw, flax and hemp have to be boiled, there is boiling liquor for which there is at present no use in the mill, and this has to be got rid of. When the kiers are blown off, if only caustic soda has been used, this will go to the soda recovery plant, but where this is not possible, as in the case where other things besides caustic are used in the boiling, the mill is faced with an effluent very difficult to render fit to be put into a river, and it is this liquor which may probably eventually have to be put into the sewer. In order that this may be as concentrated as possible, and the bulk reduced to the minimum, it seems desirable that this boiling liquor should be kept in a separate drain and run to effluent tanks where it can be kept from being diluted with other waste waters from the mill. The actual quantity from the kier itself is not great, but the trouble arises when the material is washed in washing engines, to free it from the boiling liquor, and this is then very much diluted and still very objectionable, and will have to be disposed of with the actual boiling liquor itself.

It seems that a way of dealing with this may shortly find general use in paper-mills, where the stuff, after being emptied from the kier is passed through a heavy press, which will squeeze out, in its concentrated form, about 90 per cent of this boiling liquor, which will then be added to the blow-off liquor from the boiler. After the stuff has been subjected to this pressing, and has had most of this liquor removed, the actual washing in the breaking and washing engine will require far less time and very much less water, and the waste water from this washing may be found to be easily capable of treatment which will render it fit to pass to the river.

These presses are made by Messrs. George Fletcher & Company, of Derby, and also by Messrs. Blairs Limited, of Glasgow, and are adaptations of the presses used for extracting the juice from sugar cane. They are also referred to in Chapter III.

When these types of materials are bleached and washed subsequently it will usually be found possible to recover a lot of this washing water, and also the water which contains a small amount of bleaching liquor, and pump

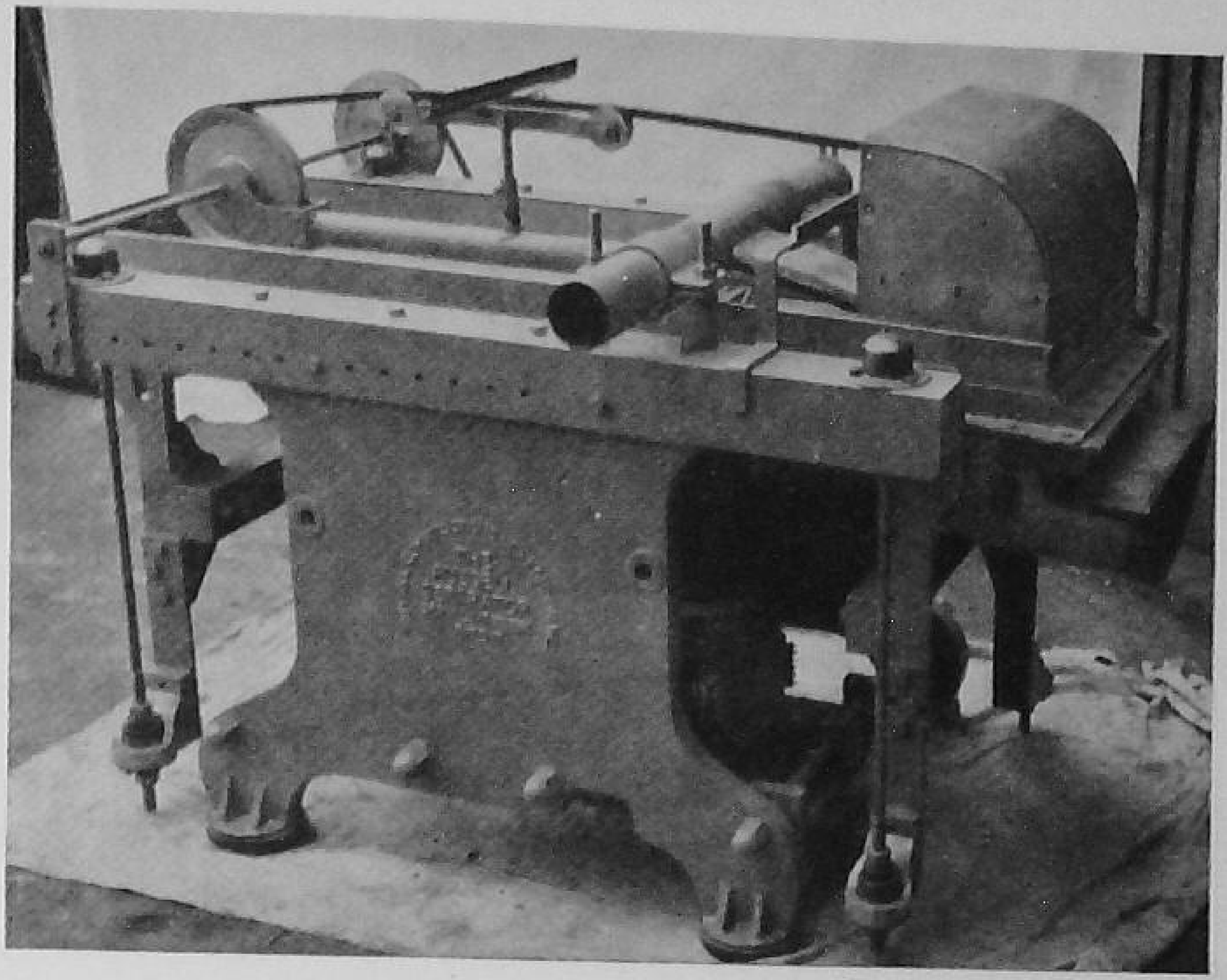
it to tanks from which it can be used for the early stages of the washing of the boiled material from the kiers. In some cases it is possible to do this and wash for, say, the first hour with the re-used water before going on to fresh water. This saves a large quantity of fresh water which, in the end, must naturally reduce the total volume of effluent, and it also has the effect of helping to start the bleaching of the fibres during their washing, as there is usually a certain amount of bleach left in the water which is washed out of the rags and similar materials immediately they have been bleached.

When every possible use has been made of all the different waste waters in the mill, there will still be some requiring treatment. As mentioned already, the actual boiling liquor is very difficult to treat, and it will probably be found cheapest in the long run to pass it into the sewer, always providing that the local authorities are prepared to accept it. The other effluent, mostly from the washing of rags, contains a certain amount of chemicals and fibre, as well as shive and other dirt, sand, etc., and there are a number of ways of dealing with this in order to clarify and purify the eventual effluent.

The first operation to be carried out on effluent is to remove the fibres because this is the only thing which can give an economic return to the mill, always providing that the fibres are in a sufficiently preserved state to be of further use for paper-making. This object is best achieved by passing the back-water or effluent through revolving save-alls. These save-alls are covered with a suitable machine wire-cloth inside. The water to be treated enters at the narrow end, passes through the mesh of the wire-cloth leaving the fibres trapped. The rotating motion of the conical screen gradually causes these fibres to pass out at the wide end of the save-all where they drop into boxes and can be taken back for further use in the mill. Where there is a lot of shive among the fibres this will also be trapped here, and will be re-treated when the fibres go back again for boiling or bleaching.

A new vibrating screen has recently been used successfully in paper-mills for removing fibres from white-water and boiling and washing liquor, and it is made by Russell Constructions Limited (Fig. 239). The machine is called the Russell Separator, and it has for its purpose the clarification of the liquid passing over it, and the regaining of the material in suspension, or the separating of the suspended matter with a view to avoiding river contamination, etc. The Russell Separator has a capacity of up to 20,000 gallons per hour, straining through 120 mesh, although the machine will work efficiently with meshes as fine as 200 or even 300. The machine is continuous in action and automatically self-cleaning, and under no circumstances can the mesh become blinded or clogged. The solid rejects pass from the machine with all but surface moisture removed. This separator has been

developed from the well-known 'Finex' sieving and straining machine, involving in principle a unique application of controlled gyratory vibration.



[*Russell Constructions Ltd.*

FIG. 239.—THE RUSSELL SEPARATOR, A VIBRATING SCREEN WITH SCRAPER BRUSHES FOR REMOVING THE FIBRES FROM WHITE-WATER AND BOILING AND WASHING LIQUORS

The material to be processed is fed to the machine through a special counter-flow nozzle, which imparts to the flow of this material a form of turbulence. When the material, in this state of motion, impinges upon the gyrating mesh, three effects come into operation.

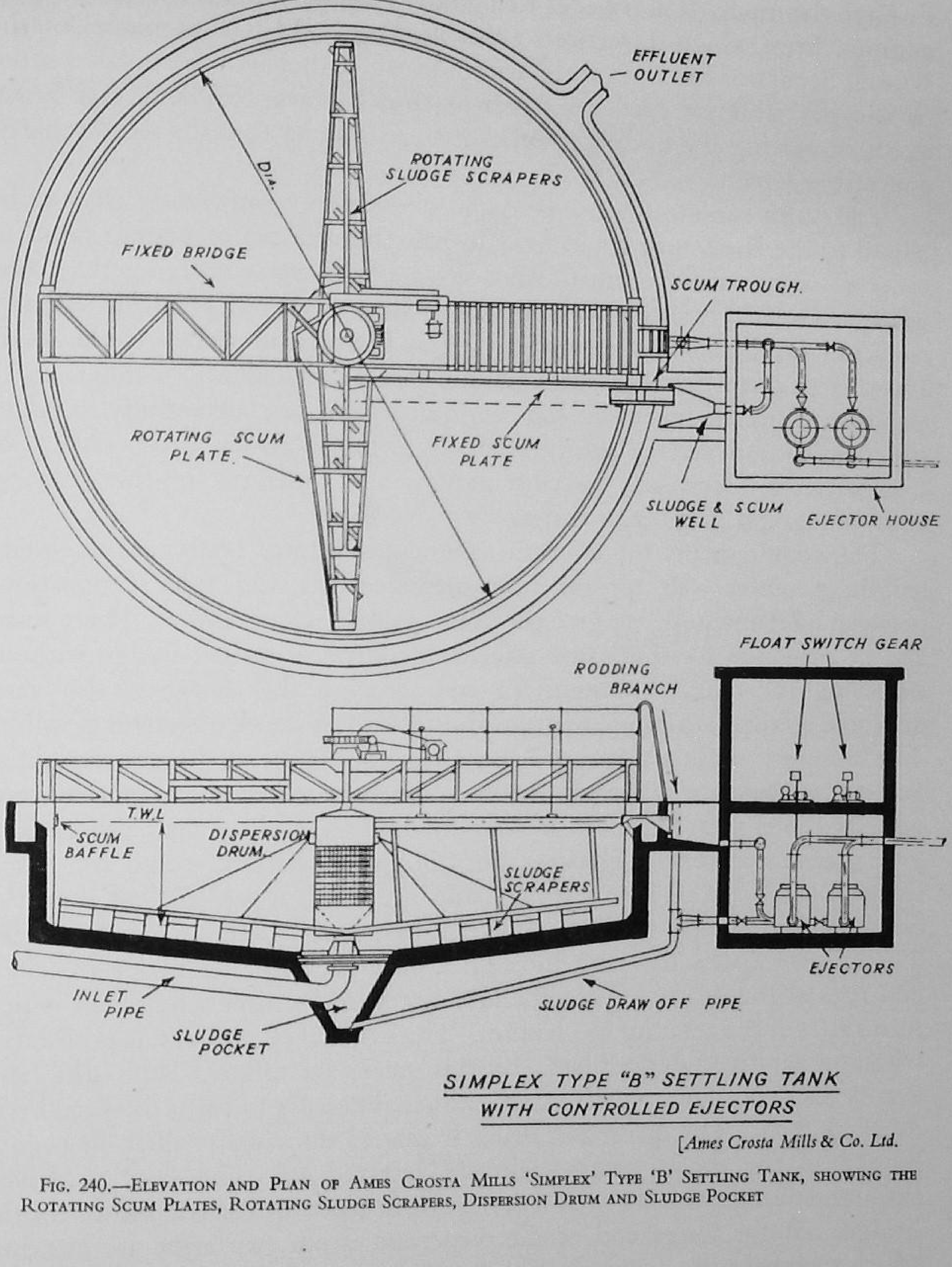
Firstly, it has the effect of forcing the liquid through the apertures of the mesh. In the second case, the liquid, as it impinges upon the gyrating mesh, has imparted to it a form of turbulence which will hold all solid and even colloidal matter in a state of suspension, and thus prevents any clogging or blinding of the mesh surface by these bodies. Thirdly, after the separation has been completed, and the de-watered material travels over the dry part of the mesh towards the reject outlet, the gyratory movement maintains in these solids a rolling motion thus getting rid of any excess liquid which may be clinging to them, and again preventing this solid matter from attempting to enter the interstices of the mesh and promote clogging, and the reject material emerges from the machine with all but surface moisture removed from it.

The machine works very well on boiling liquor containing shive and fibres, which are easily separated out, the clear liquor being allowed to pass

through the mesh. It also works well on the washing water from rag-washing engines, from which it recovers valuable fibres. The latest model of the Russell Separator has been fitted with a brush, rather like the brushes fitted to the flat strainers used on paper-machines years ago, and this brush assists in moving the fibres and other materials along towards the discharge end of the screen.

The water coming from screens and filters, if not sufficiently clear to be passed to the river, may again have to pass through sedimentation tanks in order to reduce the amount of solids in the final water entering the river. Many mills have ordinary settling tanks which usually depend for size and efficiency on the amount of room available between the mill and the river. In order to carry out this sedimentation in a more scientific manner, quite elaborate sedimentation plant has been put in and run successfully in many paper-mills, and such plant is made by Messrs. Ames Crosta Mills & Company, of Heywood, and installations are illustrated in the drawing and photograph (Figs. 240 and 241).

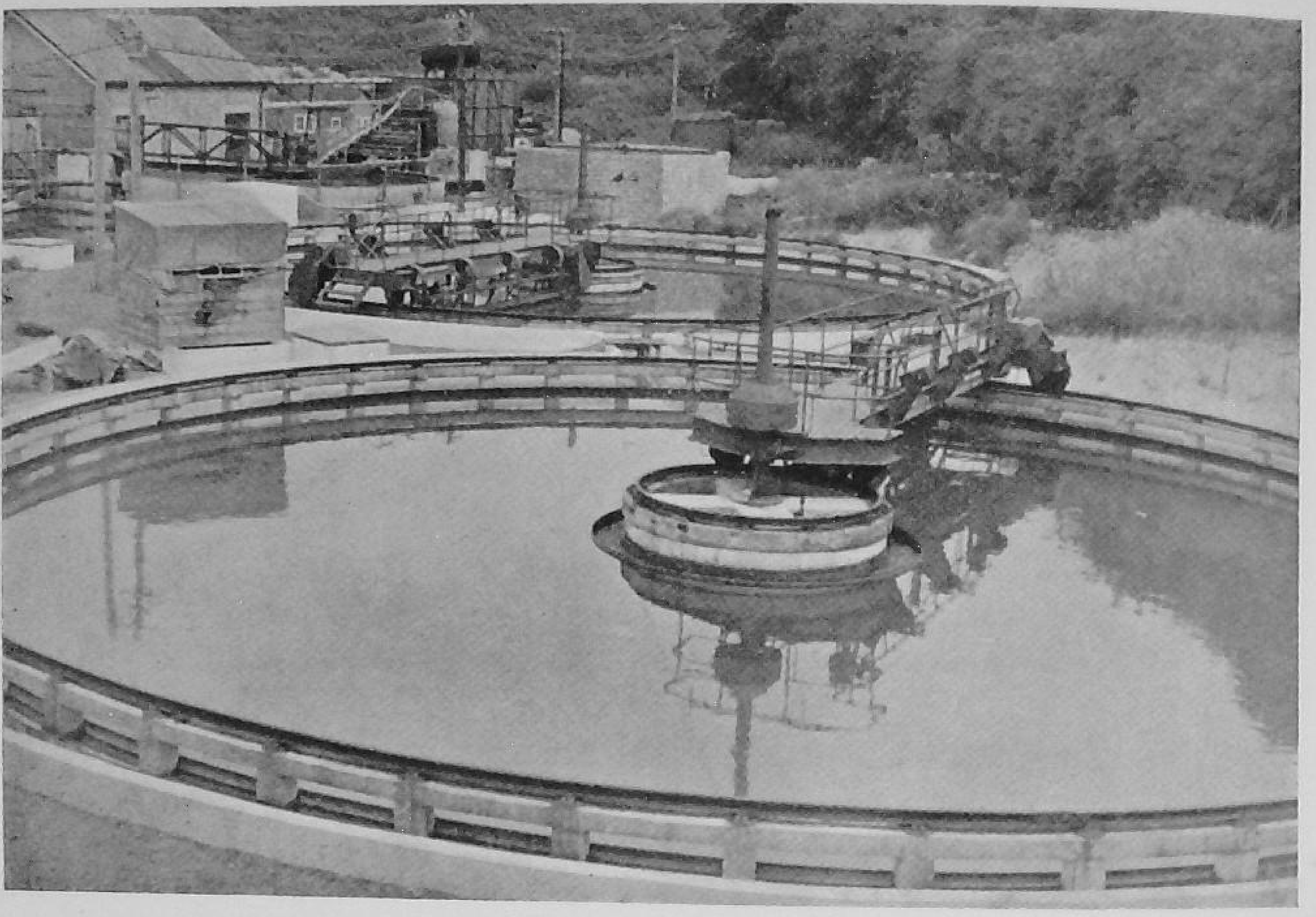
The requirements for efficient sedimentation are, firstly, an adequate length of outlet weir, proper inlet arrangements and tank proportions between inlet and outlet to give control of velocities and eddies. There must also be provision for quick and effective removal of settled sludge without emptying the tank. Provision for consolidating the sludge is also very desirable so that it is removed from the tank in as dense a state as possible. The 'Simplex' settling tanks, of Ames Crosta Mills, are of the circular radial flow type; they are relatively shallow, and have a peripheral outlet weir, perfected inlet arrangements for even distribution, and the tank proportions give precise control of velocities, and simple mechanical means for quick removal of sludge. These settling tanks are much more efficient than the ordinary rectangular settling tanks so frequently used in paper mills. The effluent enters the tank through a pipe which passes under the floor and rises at the centre. The pipe discharges into a dispersion drum which forms part of the rotating mechanism. The drum is of steel and is perforated with comparatively large holes. By this means the effluent enters the tank evenly and has a low velocity, and is directed radially towards the peripheral overflow weir. The dispersion drum is carried on a shaft which in turn is housed in the thrust bearing already referred to. The shaft is driven through substantial worm reduction gearing from an electric motor on the bridge. At the lower end of the dispersion drum two arms are attached which span the tank diametrically. A series of scraper blades hangs from the arms. The blades are set at an angle, and by the rotation of the mechanism the sludge is pushed, step by step, to the centre of the tank. Each blade



[Ames Crosta Mills & Co. Ltd.

Fig. 240.—Elevation and Plan of Ames Crosta Mills 'Simplex' Type 'B' Settling Tank, showing the Rotating Scum Plates, Rotating Sludge Scrapers, Dispersion Drum and Sludge Pocket

is attached to the arm by means of a hinge arrangement, and in a watertight housing. There is a spring which keeps the blade hanging vertically down-



[Ames Crosta Mills & Co. Ltd.

FIG. 241.—TWO 'SIMPLEX' TYPE 'A' SETTLING TANKS AND AN EXPERIMENTAL 'SIMPLEX' FILTER IN THE BACKGROUND, WORKING ON PAPER-MILL EFFLUENT, TO THICKEN THE SOLIDS AND ENABLE THE CLARIFIED WATER TO BE PASSED OUT FOR DISPOSAL

wards. The strength of the spring is such that for all normal conditions the blade remains vertical. If for any reason there is an accumulation of very heavy sludge on the floor of the tank, then the spring will yield and enable the blade to take up a more or less horizontal position. The mass of sludge is virtually moved to the centre, the blade resuming its normal vertical position. The sludge is collected in the consolidation pocket at the centre of the tank, and is drawn off under hydrostatic head through a pipe fitted with a control valve. The size of the consolidation pocket depends upon the particular application of the tank. All this is made quite clear by reference to the drawing and photograph (Figs. 240 and 241).

CHAPTER XXVII

SODA RECOVERY

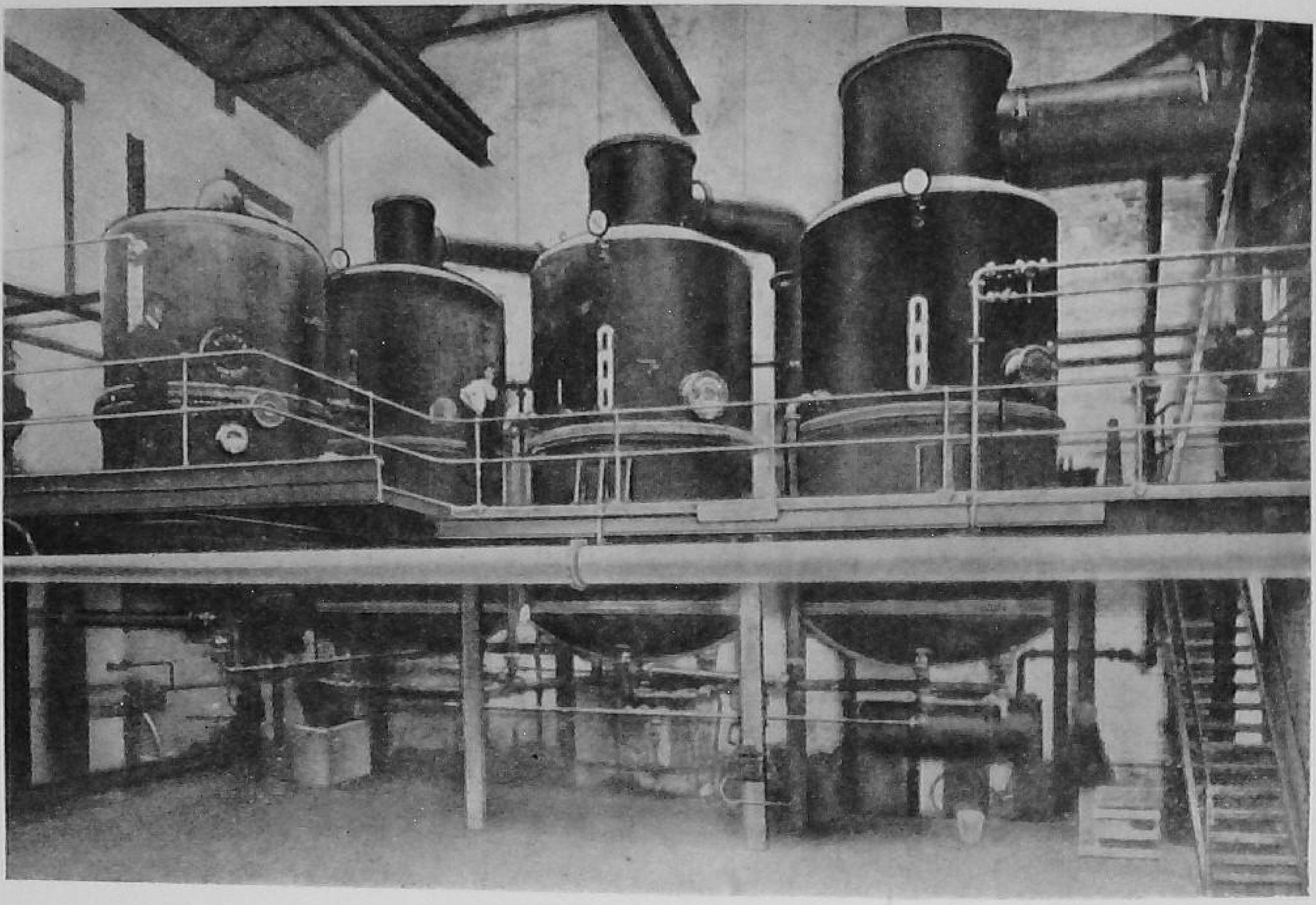
One of the most expensive items in a paper-mill using esparto, straw or rags for its raw material is the caustic soda required for boiling. In small mills, using rags or rags and wood, the spent liquor from the boilers, both in quality and quantity, is not worth the expense of installing a recovery plant. The disposal of the liquor is a continual source of trouble with the river pollution authorities, yet it must be disposed of somehow, often at great expense. When a mill is boiling esparto and using 3 to 4 cwt. of caustic soda per ton of grass, it becomes not so much a question of disposal as of recovery.

The principle of soda recovery is in itself very simple. The liquor from the boilers, containing the soda combined with the non-cellulose constituents of the raw material, is evaporated to a thick liquor and incinerated. The soda is thus converted into sodium carbonate, which is dissolved out from the incinerated mass and brought back to the caustic condition by the action of lime.

When the grass has been cooked, the steam is shut off and the vomiting action ceases as the pressure falls. The drain cock to the spent liquor reservoir is then opened and the liquor is discharged from the digester. A much better result is obtained by allowing slight pressure in the digester to express the liquid from the grass.

The cock is then shut and the boiler is filled, to above the level of the grass, with hot water obtained from the condensation of steam during the boil. Some steam is turned on to circulate the water through the pulpy mass. This wash is also run to the tank. A second wash may be carried out in the same way, but it is necessary to be careful here so that the liquor in the tank is not too much diluted for economical recovery of soda. After this, washing water may be run to the drain until the effluent is reasonably clear. A loss of soda occurs here of 2 to 5 per cent according to the efficiency of the first and second washes. The second wash may be pumped to a separate tank and used for the first wash of the next boil. Although this may reduce the work of the evaporators to some extent it is bad practice, chiefly because the colour of the grass is reduced, and any saving effected is nullified by the extra pumping and tanks required. The liquor may be run through a drum washer on its way to the tank to keep back fibre and sludge, but here again a loss takes place and the liquor is more difficult to burn, requiring to be

evaporated to a greater density. There is, of course, a risk of economizer tubes or other pipes becoming clogged up, but the regular cleaning and



[*George Scott & Son (London) Ltd.*

FIG. 242.—SCOTT QUADRUPLE EFFECT EVAPORATOR FOR CAUSTIC SODA LIQUOR

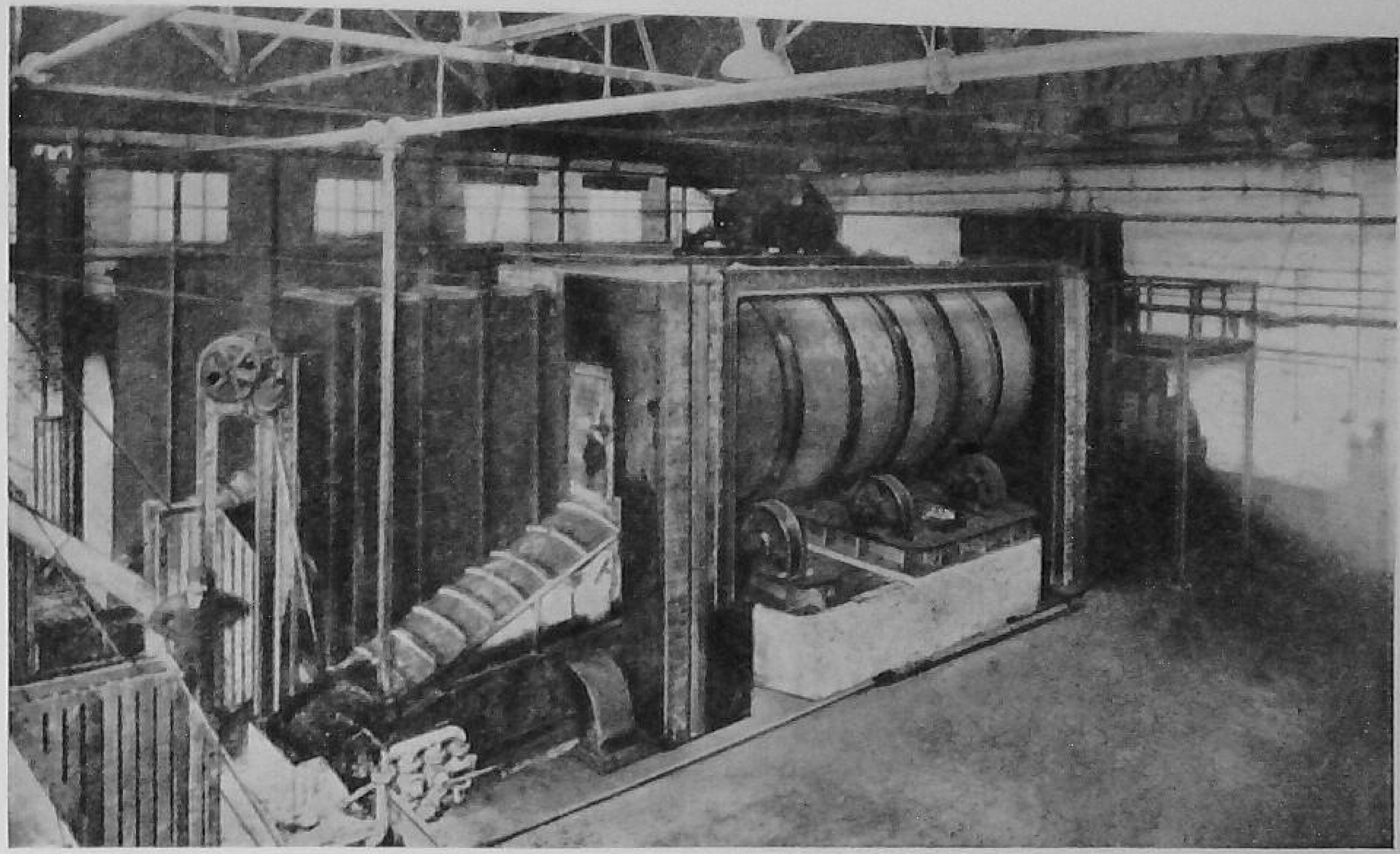
attention, which this department should receive if it is to be efficient, will reduce this to a minimum.

Evaporators are usually three in number, of which one is fed with steam from the main range. The plant is described as 'Triple Effect Vacuum Tube Evaporators'. Some plants have four evaporators and are described as Quadruple Effect (Fig. 242).

Advantage is taken of the lower boiling point induced by lessened atmospheric pressure, a vacuum being maintained by a barometric column and pump, or jet condenser. The steam created by the boiling liquor in one effect is used to bring it to a boil in the next, which is under less pressure. In some installations the liquor flows from the highest to the lowest temperature, in others the opposite way.

Each effect has three chambers, the bottom one being very shallow, the top one being much larger. The centre chamber is composed of a number of upright tubes connecting the top and the bottom, through which

the liquor is agitated by means of the vacuum. The steam to assist the evaporation of this liquid is passed through the centre chamber, but on the



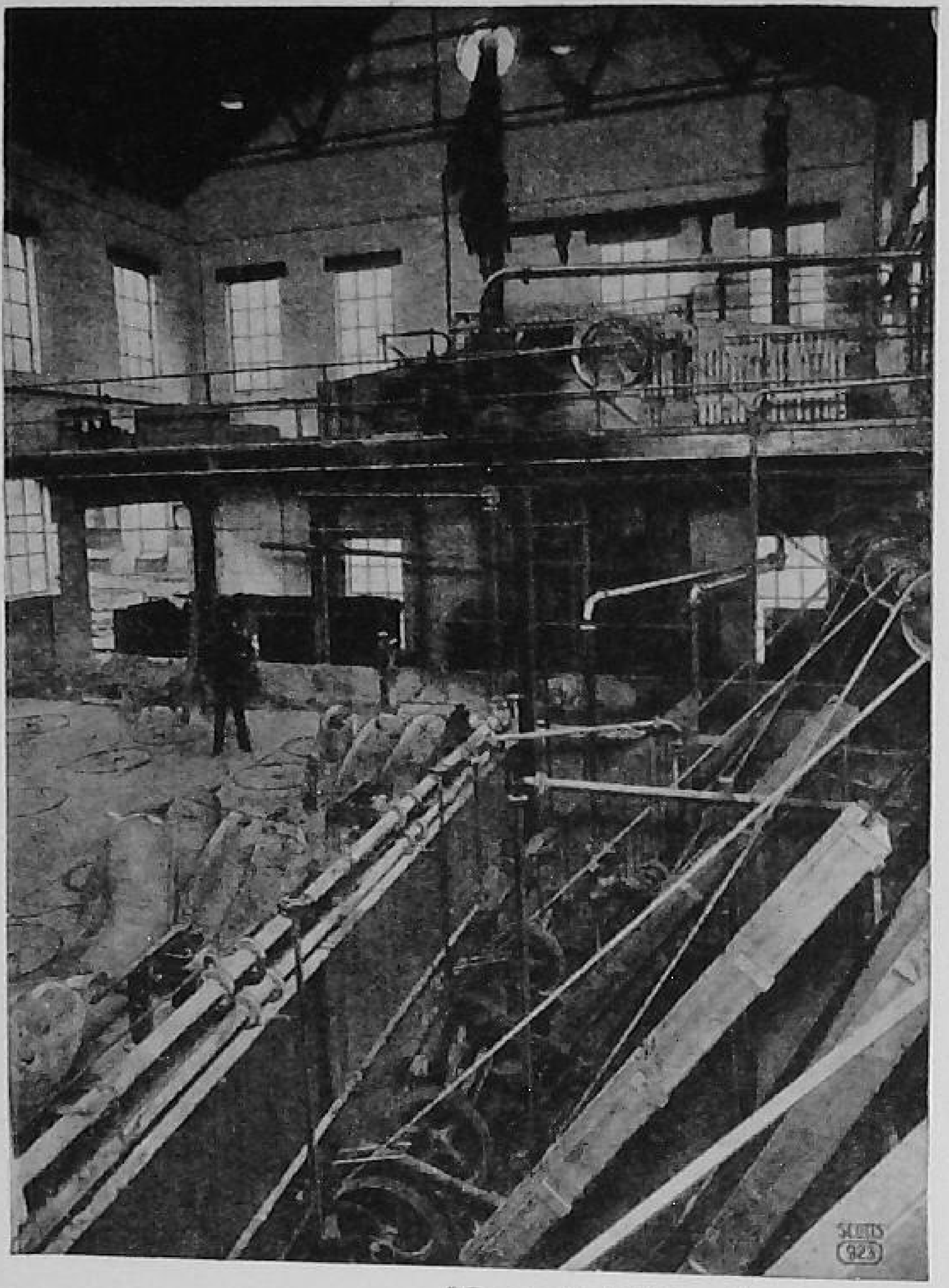
[*George Scott & Son (London) Ltd.*

FIG. 243.—SCOTT ROTARY FURNACES WITH PATENT SODA GRATES

outside of the tubes. The last effect or concentrator is constructed in the same manner as Nos. 1 and 2, but the steam for this concentrator is new steam, procured entirely from the main steam range. This ensures that the thickened liquor is passing to the furnace at the highest temperature, the drop in temperature being from the third to the first effect in this arrangement. Where the drop in temperature is from the first to the third effect, the thickened liquor requires to be run to a steam-heated storage tank to increase its temperature, thereby making it more fluid and easy to burn.

The liquor has then been concentrated from about 4° Tw. to 60° Tw. (200° to 230° F.) by evaporation, and passes onwards to the rotary furnace (Fig. 243). This consists of a revolving firebrick-lined steel shell, whose internal diameter increases towards the discharge end. It revolves about once per minute. Ignition of the liquor is caused in the first place by a gas flame, or an auxiliary furnace with coal, oil or wood at the start of a run, and with careful control the liquor will then remain alight throughout the run. In one type of furnace the liquor is sprayed in similarly to an oil-fired boiler.

Combustion is sustained by the burning of the organic matter brought forward with the liquor from the digesters.



[George Scott & Son (London) Ltd.

FIG. 244.—CAUSTICISERS AND, IN REAR, ROTARY VACUUM FILTER

There are several methods of subsequent treatment of the black ash. One method is to complete the combustion of all remaining carbon on a travelling chain grate over forced draught. Another consists in removing the ash from the furnace while combustion is still incomplete and spreading this ash over a perforated floor under which an air draught is induced. Complete combustion requires about 2 weeks under these conditions. This method has the disadvantage of requiring a long time and a good deal of floor area. The calcined ash, or 'black ash', is then soaked with boiling water, which absorbs all the sodium carbonate, and this is drained to a pump through perforated tiles in the bottom of the soaking tank. This liquor is then pumped to a causticising pan (Fig. 244) with a half-round bottom and a mechanical agitator. A quantity of pure 'make-up' sodium carbonate is then added, with the necessary amount of lime, to the causticiser, where it is dissolved by boiling and agitation. The aim of the whole operation is to retain the maximum amount of sodium carbonate, any losses being replaced at the causticiser.

The required amount of lime is then added to the causticiser, the action being chemically designated so:

$$Na_2CO_3+CaO+H_2O=CaCO_3+2NaOH$$

Up to 45 per cent of lime is required, and the whole is subsequently boiled for from 1 to 2 hours with direct steam and continuous agitation. Agitation then ceases and solids, principally chalk and carbon, are allowed to settle. 'Strong' liquor may then be drawn from the top of the causticiser. It is then recharged with water and agitated for a further hour. The solids

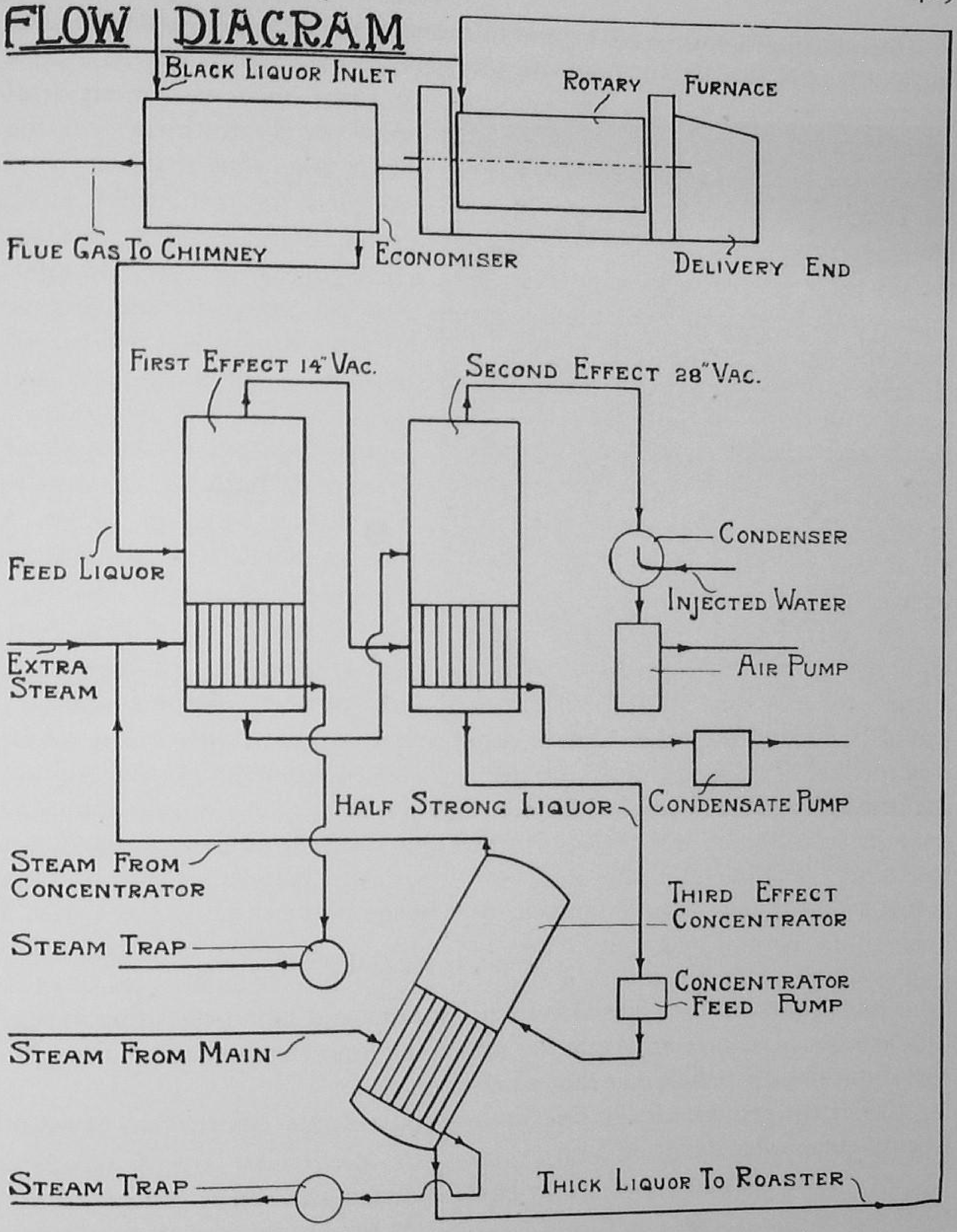


FIG. 245.—FLOW DIAGRAM OF CAUSTIC SODA RECOVERY PROCESS

are then again allowed to settle as before and a weaker liquor is drawn off. These two batches are then mixed and give a batch of boiling liquor at somewhere about 14°Tw. The causticiser is again filled with water and agitated as before, and when all solids have settled out the resulting liquor is drawn off and serves as a 'water' for the next 'weak' liquor production.

The losses, which are inevitable, result from carrying off sodium carbonate in the digested grass, in the sludge from the drum washer, if used, in the vapour from the evaporating plant, by particle entrainment in the rotary furnace flue gases, and incomplete recovery from the black ash, and sludge from the causticiser pans. The sludge left in the causticiser pan is a very difficult problem. It may be drawn off and settled in ponds, the liquor from the surface being run away and the sludge being dug out and deposited in some waste ground. It can be readily understood that there may be many difficulties in this proceeding, as it is not easy to find sufficient waste ground to dispose of the sludge from a large mill. It is possible, however, to dry this sludge and recondition it so that it may be used as lime for agricultural purposes.

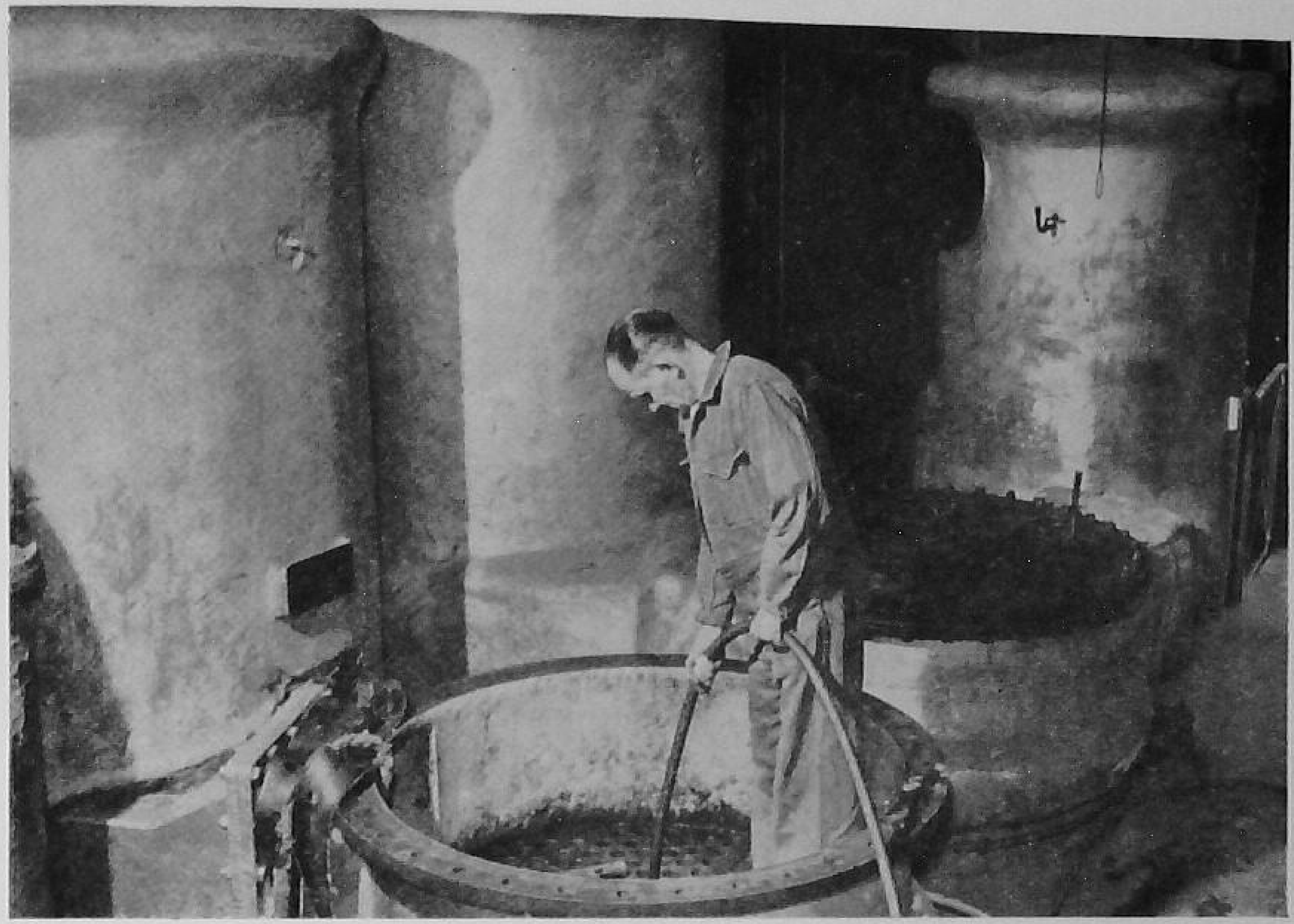
The recovery of from 70 to 80 per cent is possible economically, and higher recoveries than this have been claimed. Although it is theoretically possible to recover nearly 100 per cent of the original soda used, the expense would be greater than the value of the recovered soda. Where there is no easy method of disposing of sludge and extra washings of the grass owing to the proximity of a preserved river, recovery has to be of the utmost possible quantity in order to satisfy River Authorities. In this case extra expense is, of course, inevitable and unavoidable.

Kestner Patent Climbing Film Evaporator

The Kestner Patent Climbing Film Evaporator differs from other types in a number of important respects of which the most fundamental is the fact that a different principle of evaporation is used.

Briefly the principle is that the liquor is fed continuously into the bottom of a calandria which is fitted with a number of long vertical large-bore tubes expanded into top and bottom tubeplates, the steam shell being of a relatively small diameter compared with other types. As the liquor rises up the tubes, evaporation takes place, the vapour forming a core in the centre and carrying with it the liquor as a film in contact with the inner walls of the tube. At the top the mixture of liquor and vapour is discharged at high velocity into a separator placed to one side of the calandria. The latter is fitted with easily

removable covers, top and bottom, through which the tubes are readily accessible for cleaning or renewal.



[*Kestner Evaporator & Engineering Co. Ltd.*

Fig. 246.—View of top platform of Kestner Triple Effect Evaporator, illustrating simplicity of tube cleaning

This design has the following advantages in respect of keeping the heating surface free from scale:

1. Cleaning can commence immediately since there is no waiting for the plant to cool down.
2. The operator works in comfort since he is not required to enter a hot evaporator.
3. A small number of tubes are more quickly cleaned than a large number of short tubes.

The cleaning of a typical Kestner Triple Effect black liquor evaporator installed in a British paper mill is illustrated on figure 246. This photograph shows the operator in the act of cleaning the second effect. The third effect calandria is behind the operator and in the background are the liquor/vapour separators. It will be seen how accessible the tubes are for cleaning from all sides.

The frequency of cleaning with this type of evaporator, as with others, depends on the nature of the liquor and the conditions of working. With

the long tube vertical evaporator, however, due to the high velocity of liquor in the tubes, scaling is less than in other types and on an average only one calandria out of three in a normal black liquor Triple Effect requires cleaning every week.

The separators of a Kestner evaporator are of the tangential type and the high velocity of liquor and vapour entering at the tangential is made use of to effect separation by centrifugal force. Since the evaporator is continuous in operation the proportions of these separators can be correctly calculated for conditions of use with the result that trouble due to foaming and loss of liquor by entrainment is eliminated.

Another feature of the Climbing Film Principle is that the plant holds only a small volume of liquor. Thus the danger of a 'boil-over' occurring due to a change of pressure or vacuum is eliminated. For the same reason, starting up is rapid, and even with big plants the desired density is obtained from the third effect inside an hour of starting.

Due to the relatively small diameter of the calandrias even on a large plant the floor space occupied is appreciably less than with other types. The height of the evaporator itself, however, is about 30 feet. In most cases this height is taken advantage of to obtain barometric discharge for the liquor and for the condenser cooling water. With this arrangement the pumps required for the evaporator are limited to two ; namely, a feed pump and a third effect condensate extraction pump. Maintenance costs are thus minimized.

Alternatively, if height is limited the evaporator can be mounted at a lower level and the necessary extraction pumps provided.

Kestner Evaporators are in general use for the concentration of liquors resulting from various raw materials both by the soda and by the sulphate processes. Usually a Triple or Quadruple Effect is employed for the concentration up to 45/60° Tw. For higher concentrations the Multiple Effect is followed by a Single Effect Finisher, and this may be either of the Climbing Film type or the Forced Circulation type depending on circumstances. Usually the finisher operates at atmospheric pressure so as to provide a hot liquor for delivery to the roaster. Exhaust vapour from the Finisher is used in the Multiple Effect for preheating liquor, thereby obtaining the maximum steam economy.

APPENDIX OF TABLES

Moisture in Paper on Machines

The following tables show the percentage of moisture contained in the web from the breast box to the finishing house, and also the proportion of water to dry fibre.

FOURDRINIER

Class of Paper	*White News*		*Common News*	
Substance in D.C. 500's	25 lb.		21½ lb.	
Speed	580 ft.		590 ft.	
	%	*Parts water per part fibre*	%	*Parts water per part fibre*
Breast box	98.92	91.6	99.2	124.0
Couch	77.6	3.46	78.1	3.57
First press	73.1	2.59	75.5	3.08
Second press	69.3	2.25	71.6	2.52
Third press	68.4	2.16	71.6	2.52
Middle cylinder	41.1	0.69	49.1	0.96
Machine calenders	6.2	0.06	7.0	0.08
After damping	12.2	0.14	9.4	0.10
After super-calender	7.2	0.08	8.8	0.10

Length of machine wire, 70 feet. Six suction boxes. First press, maple; second press, granite; third press, brass. All on rubber. Thirty 5 feet 6 inch drying cylinders. Cooling roll at reeling drum. Spray damper before reeling drum.

FOURDRINIER

Class of Paper	*Mechanical Printing*		*Antique Wove Printing*	
Substance in D.C. 500's	21½ lb.		68 lb.	
Speed	330 ft.		140 ft.	
	%	*Parts water per part fibre*	%	*Parts water per part fibre*
Breast box	99.0	99.0	97.8	44.4
Couch	85.1	5.71	80.0	4.0
First press	69.6	2.29	63.4	1.73
Second press	64.9	1.85	61.4	1.59
Intermediate rolls	—	—	17.3	0.21
Machine calenders	6.2	0.07	4.8	0.05
After damping	10.6	0.12	—	—
After super-calender	8.2	0.09	—	—
After cutting and finishing	—	—	5.2	0.05

This machine had a wire 50 feet long, and iron first and second top press rolls, with rubber bottom rolls. There were twenty-two 5-feet drying cylinders.

FOURDRINIER

Class of Paper	*Tissue*	
Substance in D.C. 500's	9.17 lb.	
Speed	350 ft.	
	%	*Parts water per part fibre*
Breast box	99.52	207.0
Couch	84.3	5.37
First press	70.2	2.35
Second press	68.5	2.17
Middle cylinder	47.3	0.90
Reel	4.5	0.05

M.G. MACHINE

Class of Paper	*Pure Sulphide*		*'Manilla' Envelope Paper*	
Substance in D.C. 500's	16 lb.		32 lb.	
Speed	150 ft.		140 ft.	
	%	*Parts water per part fibre*	%	*Parts water per part fibre*
Breast box	99.4	165.7	98.8	82.3
Couch	85.0	5.67	81.4	4.38
First press	68.3	2.16	69.9	2.32
Before M.G. cylinder	65.6	1.91	68.0	2.13
At reel	5.6	0.06	5.6	0.06

M.G. MACHINE

Class of Paper	*Pressing or Cover Paper*		*Sulphite Litho*	
Substance in D.C. 500's	47½ lb.		32½ lb.	
Speed	91 ft.		100 ft.	
	%	*Parts water per part fibre*	%	*Parts water per part fibre*
Breast box	98.6	70.4	99.0	99.0
Couch	78.5	3.65	73.9	2.83
First press	67.1	2.04	58.3	1.40
Before M.G. cylinder	60.9	1.56	—	—
At reel	3.4	0.04	4.4	0.05

Moisture Removed by the Couch Rolls

It is sometimes asserted that the couch rolls do not remove any appreciable amount of water from the web. This is not so. The result of several tests showed that about 10 per cent of water is removed, or the proportion of water to fibre is almost halved.

Moisture in web before couch roll 86·85 per cent, or 6·60 parts water per part fibre.

Moisture in web after couch roll 78·64 per cent, or 3·68 parts water per part fibre.

The moisture content is estimated on the wet pulp weight.

The paper was pure sulphite and the substance 24½ lb. demy.

COLOUR REACTIONS OF FIBRES BY COMMON STAINS

Fibre	*Iodine and Zinc Chloride*	*Iodine and Sulphuric Acid*	*Aniline Sulphate*	*Phloroglucinol*
Cotton	Violet	Blue	—	—
Flax	Violet	Blue	—	—
Hemp	Violet	Blue	Pale yellow	Violet red
Jute	Brown yellow	Green blue	Golden yellow	Deep red
Ramie	Dull violet	Dull blue	—	—
Manilla hemp	Yellow to violet	—	Yellow	Red
New Zealand flax	Golden yellow	Green blue	Yellowish	Pale red
Chemical wood	Blue violet	Blue to grey	Pale yellow	Pale red
Mechanical wood	Yellow	Dark yellow	Dark yellow	Deep red

Iodine and Zinc Chloride (*Herzberg Stain*). Dissolve 20 grm. zinc chloride in 10 ml. water and add to a solution of 2·1 grm. potassium iodide and 0·1 grm. iodine in 5 ml. water. Allow to stand for 24 hours and decant the clear solution, and finally add a crystal of iodine to the clear solution. Place a drop of the solution on the disintegrated and teased fibres and mop up the excess stain to avoid too deep a coloration.

Iodine and Sulphuric Acid. Dissolve 2·85 grm. iodine and 5·0 grm. potassium iodide in 100 ml. water. Add 5 ml. glycerine.

Spot the fibre mass with the iodine solution, mop up the excess stain after standing 2 minutes and add a spot of sulphuric acid solution (70 ml. concentrated sulphuric acid added to 30 ml. water).

Aniline Sulphate. Dissolve 1 grm. aniline sulphate in 50 ml. water and apply solution as with iodine stains.

Phloroglucinol. Dissolve 1 grm. phloroglucinol hydrochloride in 50 ml. ethyl alcohol and add 25 ml. concentrated hydrochloric acid. Apply the stain as with iodine stains.

EQUIVALENT WEIGHTS OF WRITING PAPERS EXPRESSED IN TERMS OF LB. 480's

Large Post (16½ × 21)	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Foolscap (16½ × 13¼)	7	7⅝	8⅞	9½	10⅛	10¾	11⅜	12	12⅝	13¼	14	14⅝	15¼	15⅞	16½	17⅛	17¾	18⅜	19	19⅝	20¼	20⅞	21½	22⅛
Pinched Post (18½ × 14¾)	8¾	9½	11⅛	11¾	12⅝	13½	14¼	15	15¾	16⅝	17⅜	18⅛	19	19¾	20½	21⅜	22⅛	22⅞	23⅝	24½	25¼	26	26⅞	27⅝
Post (19 × 15¼)	9¼	10⅛	11¾	12⅝	13½	14¼	15⅛	16	16¾	17⅝	18½	19¼	20⅛	21	21¾	22⅝	23½	24¼	25⅛	26	26⅞	27⅝	28½	29⅜
Demy (20 × 15½)	9⅞	10¾	12⅝	13½	14⅜	15¼	16⅛	17	18	18⅞	19¾	20⅝	21½	22⅜	23⅜	24¼	25⅛	26	26⅞	27¾	28¾	29⅝	30½	31⅜
Medium (22 × 17½)	12¼	13⅜	15⅝	16¾	17⅞	19	20	21⅛	22¼	23⅜	24½	25⅝	26¾	27⅞	29	30	31⅛	32¼	33⅜	34½	35⅝	36¾	37⅞	39
Royal (24 × 19)	14½	15⅞	18½	19¾	21⅛	22⅜	23¾	25⅛	26⅜	27¾	29	30⅜	31⅝	33	34¼	35⅝	36⅞	38¼	39½	40⅞	42⅛	43½	44¾	46⅛
Super Royal (27 × 19)	16⅜	17⅞	20¾	22¼	23¾	25¼	26¾	28¼	29⅝	31⅛	32⅝	34⅛	35⅝	37⅛	38½	40	41½	43	44½	46	47½	48⅞	50⅜	51⅞
Imperial (30 × 22)	21	22⅞	26¾	28⅝	30½	32½	34⅜	36¼	38⅛	40	42	43⅞	45¾	47⅝	49⅝	51½	53⅜	55¼	57¼	59⅛	61	62⅞	64⅞	66¾
Sheet and ⅓ Foolscap (22 × 13½) ..	9½	10⅜	12	12⅞	13¾	14⅝	15½	16⅜	17¼	18	18⅞	19¾	20⅝	21½	22⅜	23¼	24	24⅞	25¾	26⅝	27½	28⅜	29¼	30
Sheet and ½ Foolscap (24¾ × 13½)	10½	11½	13⅜	14⅜	15⅜	16¼	17¼	18¼	19⅛	20⅛	21	22	23	23⅞	24⅞	25⅞	26¾	27¾	28¾	29⅝	30⅝	31½	32½	33½
Double Foolscap (26½ × 16½) ..	14	15¼	17¾	19	20¼	21½	22¾	24	25¼	26½	27⅞	29⅛	30⅜	31⅝	32⅞	34⅛	35⅜	36⅝	37⅞	39⅛	40½	41¾	43	44¼
Double Large Post (33 × 21) ..	22	24	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70
Double Demy (31 × 20)	19¾	21½	25⅛	26⅞	28¾	30½	32¼	34	35⅞	37⅝	39⅜	41	43	44¾	46⅝	48⅜	50⅛	52	53¾	55½	57⅜	59⅛	60⅞	62¾

EQUIVALENT WEIGHTS OF PRINTING PAPERS EXPRESSED IN TERMS OF LB. 480's

Demy (22½ × 17½)	11	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	30	32	34	36	38	40
Large Post (21 × 16½)	9¾	11½	12⅜	13¼	14⅛	15	15⅞	16¾	17⅝	18½	19⅜	20¼	21⅛	22	23	23⅞	24¾	26½	28¼	30	31¾	33½	35¼
Medium (18 × 23)	11⅝	13¾	14¾	15⅞	16⅞	17⅞	19	20	21⅛	22⅛	23¼	24¼	25¼	26⅜	27⅜	28½	29½	31⅝	33¾	35¾	37⅞	40	42⅛
Royal (25 × 20)	14	16⅝	17⅞	19⅛	20⅜	21⅝	22⅞	24¼	25½	26¾	28	29¼	30½	31¾	33⅛	34¾	35⅝	38⅛	40¾	43¼	45¾	48⅜	50⅞
Super Royal (27½ × 20)	15⅞	18⅝	20⅛	21½	23	24⅜	25⅞	27¼	28¾	30⅛	31⅝	33	34⅜	35⅞	37¼	38¾	40⅛	43	45⅞	48¾	51⅝	54½	57⅜
Imperial (22 × 30)	18½	21⅞	23½	25¼	26⅞	28½	30¼	31⅞	33⅝	35¼	36⅞	38⅝	40¼	42	43⅝	45⅜	47	50⅜	53¾	57	60⅜	63¾	67½
Double Foolscap (27 × 17) ..	12⅞	15¼	16⅜	17½	18⅝	19⅞	21	22⅛	23⅜	24½	25⅝	26⅞	28	29⅛	30⅜	31½	32⅝	35	37¼	39⅝	42	44¼	46⅝
Sheet and ½ Post (23½ × 19½) ..	12⅞	15¼	16⅜	17½	18¾	19⅞	21	22⅛	23⅜	24½	25⅝	26⅞	28	29⅛	30⅜	31½	32⅝	35	37¼	39⅝	42	44¼	46⅝
Double Crown (30 × 20) ..	16⅞	19⅞	21⅜	22⅞	24½	26	27½	29	30½	32	33⅝	35⅛	36⅝	38⅛	39⅝	41¼	42¾	45¾	48⅞	51⅞	54⅞	58	61
Double Large Post (33 × 21) ..	19⅜	23	24¾	26½	28¼	30	31¾	33½	35¼	37	38¾	40½	42½	44	45⅞	47⅝	49⅜	52⅞	56⅜	59⅞	63⅜	67	70½
Double Demy (35 × 22½)	22	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	60	64	68	72	76	80
Double Royal (40 × 25)	28	33⅛	35⅝	38⅛	40¾	43¼	45¾	48⅜	50⅞	53⅜	56	58½	61	63½	66⅛	68⅝	71⅛	76¼	81⅜	86⅜	91½	96⅝	101⅝
Quad Crown (40 × 30)	33⅝	39⅝	42¾	45¾	48⅞	51⅞	54⅞	58	61	64	67⅛	70⅛	73¼	76¼	79¼	82⅜	85⅜	91½	97⅝	103⅝	109¾	115⅞	122

SUBSTANCE EQUIVALENTS: GRAMMES AND POUNDS

Grammes per Square Metre	*Demy* ($22\frac{1}{2} \times 17\frac{1}{2}$)			*Royal* (25×20)			*Double Foolscap* (27×17)			*Double Crown* (30×20)		
	480's *Lb.*	500's *Lb.*	516's *Lb.*	480's *Lb.*	500's *Lb.*	516's *Lb.*	480's *Lb.*	500's *Lb.*	516's *Lb.*	480's *Lb.*	500's *Lb.*	516's *Lb.*
20	5.38	5.6	5.78	6.82	7.1	7.33	6.26	6.52	6.73	8.19	8.53	8.8
21	5.64	5.88	6.06	7.16	7.46	7.7	6.57	6.84	7.06	8.6	8.96	9.24
22	5.91	6.16	6.35	7.5	7.81	8.06	6.89	7.17	7.4	9.01	9.39	9.68
23	6.18	6.44	6.64	7.84	8.16	8.43	7.2	7.5	7.74	9.42	9.81	10.13
24	6.45	6.73	6.93	8.18	8.52	8.79	7.51	7.82	8.07	9.83	10.24	10.57
25	**6.72**	**7.0**	**7.22**	**8.52**	**8.87**	**9.16**	**7.82**	**8.15**	**8.41**	**10.24**	**10.67**	**11.01**
26	6.99	7.28	7.51	8.87	9.23	9.53	8.14	8.48	8.75	10.65	11.09	11.45
27	7.26	7.56	7.8	9.21	9.59	9.9	8.45	8.8	9.08	11.06	11.52	11.89
28	7.53	7.84	8.09	9.55	9.95	10.27	8.76	9.12	9.42	11.47	11.95	12.23
29	7.8	8.12	8.38	9.89	10.3	10.63	9.08	9.45	9.76	11.88	12.38	12.77
30	**8.06**	**8.4**	**8.66**	**10.23**	**10.66**	**11.0**	**9.39**	**9.78**	**10.09**	**12.29**	**12.8**	**13.21**
31	8.33	8.68	8.95	10.57	11.01	11.36	9.7	10.1	10.43	12.7	13.23	13.65
32	8.6	8.96	9.24	10.91	11.36	11.73	10.02	10.43	10.77	13.11	13.66	14.09
33	8.87	9.24	9.53	11.25	11.71	12.09	10.33	10.76	11.1	13.52	14.08	14.53
34	9.14	9.52	9.82	11.59	12.07	12.46	10.64	11.08	11.44	13.93	14.51	14.97
35	**9.41**	**9.8**	**10.11**	**11.93**	**12.43**	**12.83**	**10.95**	**11.41**	**11.77**	**14.34**	**14.93**	**15.42**
36	9.68	10.08	10.41	12.28	12.79	13.2	11.27	11.74	12.11	14.75	15.36	15.86
37	9.95	10.36	10.7	12.62	13.15	13.57	11.58	12.06	12.45	15.16	15.79	16.3
38	10.21	10.64	10.98	12.96	13.5	13.93	11.89	12.39	12.78	15.57	16.22	16.74
39	10.48	10.92	11.27	13.3	13.85	14.29	12.21	12.72	13.12	15.98	16.64	17.18
40	**10.75**	**11.2**	**11.56**	**13.64**	**14.21**	**14.66**	**12.52**	**13.04**	**13.46**	**16.38**	**17.06**	**17.61**
41	11.02	11.48	11.85	13.98	14.56	15.02	12.83	13.37	13.79	16.79	17.49	18.05
42	11.29	11.76	12.14	14.32	14.91	15.39	13.15	13.7	14.13	17.2	17.92	18.49
43	11.56	12.04	12.43	14.66	15.27	15.76	13.46	14.02	14.47	17.61	18.34	18.93
44	11.83	12.32	12.72	15.0	15.62	16.12	13.77	14.34	14.8	18.02	18.77	19.37
45	**12.1**	**12.6**	**13.01**	**15.34**	**15.98**	**16.49**	**14.08**	**14.67**	**15.14**	**18.43**	**19.2**	**19.81**
46	12.36	12.88	13.29	15.69	16.34	16.86	14.4	15.0	15.48	18.84	19.62	20.25
47	12.63	13.16	13.58	16.03	16.7	17.23	14.71	15.32	15.81	19.25	20.05	20.69
48	12.9	13.44	13.87	16.37	17.06	17.6	15.02	15.65	16.15	19.66	20.48	21.13
49	13.17	13.72	14.16	16.71	17.41	17.96	15.34	15.97	16.49	20.07	20.91	21.57
50	**13.44**	**14.0**	**14.45**	**17.05**	**17.76**	**18.33**	**15.65**	**16.3**	**16.82**	**20.48**	**21.33**	**22.02**
60	16.12	16.8	17.33	20.46	21.3	21.99	18.78	19.56	20.18	24.58	25.6	26.42
70	18.88	19.6	20.22	23.86	24.85	25.66	21.9	22.81	23.54	28.68	29.87	30.83
80	21.5	22.4	23.11	27.27	28.4	29.32	25.03	26.0	26.91	32.77	34.13	35.23
90	24.19	25.2	26.0	30.68	31.96	32.98	28.16	29.33	30.27	36.86	38.4	39.63
100	26.88	28.0	28.9	34.1	35.52	36.65	31.3	32.6	33.64	40.96	42.67	44.03

Rough Methods.—(1) Grammes per square metre multiplied by $0.41 =$ weight 20×30 480's. Example: $30 \times 0.41 = 12.30$ lb. (2) Weight per ream 480's $\times 1464 \div$ area in inches gives grammes per square metre. Example: $15 \times 1464 \div 25 \times 20 = 44$ grammes.

Strawboards: Equivalent Number per Cwt.

Weight of Board	22 × 32 704	20 × 25 500	20 × 30 600	24 × 38 912	25 × 30 750	27 × 34 918	28 × 36 1008	30 × 40 1200
4 oz.	448	631	526	346	421	344	313	263
6 „	299	421	354	231	281	229	209	175
8 „	224	315	263	173	210	172	156	131
10 „	179	252	210	138	168	137	125	105
12 „	149	210	175	115	140	113	104	87
14 „	128	180	150	99	120	98	89	75
16 „	112	158	131	86	105	86	78	66
18 „	100	141	117	77	94	77	70	59
20 „	90	127	106	69	84	69	63	53
1½ lb.	75	106	88	58	70	58	52	44
1¾ „	64	90	75	49	60	49	45	38
2 „	56	79	66	43	53	43	39	33
2¼ „	50	70	59	39	47	38	35	29
2½ „	45	63	53	35	42	35	31	26
2¾ „	41	58	48	32	38	31	29	24
3 „	37	52	43	29	35	28	26	22
3½ „	32	45	38	25	30	25	22	19
4 „	28	39	33	22	26	21	20	16

Basis, 22 × 32. The figures under size in heading indicate square inches.

French and Belgian Sizes of Paper

Name	*Size in Centimetres*	*Size in Inches*	*Name*	*Size in Centimetres*	*Size in Inches*
Grand Aigle ..	104 × 70	41 × 27⅝	Carré	56 × 45	22⅛ × 17¾
Grand Colombier ..	90 × 63	35½ × 24⅞	Coquille	56 × 44	22⅛ × 17⅜
Colombier	85 × 62	33½ × 24½	Petit Médian ..	53.3 × 40	21 × 15¾
Petit Aigle ..	84 × 60	33⅛ × 23⅝	Ecu	52 × 40	20½ × 15¾
Petit Colombier ..	80 × 60	31½ × 23⅝	Couronne	46 × 36	18⅛ × 14¼
Grand Soleil.. ..	80 × 57	31½ × 22½	Ruche	46.2 × 36	18¼ × 14¼
Elephant	77 × 62	30⅜ × 24½	Griffen	45 × 35	17¾ × 13⅞
Jesus	76 × 56	30 × 22⅛	Tellière	44 × 34	17⅜ × 13½
Jesus	70 × 55	27⅝ × 21¾	Propatria	43 × 34.5	17 × 13⅝
Super Royal ..	70 × 50	27⅝ × 19¾	Almasso	44 × 32.5	17⅜ × 12⅞
Petit Soleil	68 × 50	26⅞ × 19¾	Petit Raisin ..	43 × 32	17 × 12⅝
Raisin	65 × 50	25⅝ × 19¾	Pot	40 × 31	15¾ × 12¼
Royal	63 × 48	24⅞ × 19	Cloche	40 × 30	15¾ × 11⅞
Cavalier	62 × 46	24½ × 18⅛	Lys	39.7 × 31.7	15⅝ × 12½
Grand Médian ..	60.5 × 46	23⅞ × 18⅛	Rosette	34.7 × 27	13¾ × 10⅝

The above is a selection from an extensive range of prevailing sizes. The dimensions given are those most frequently used; but there is considerable variation in different qualities of papers and different makers.

Equivalent Sizes in Inches and Centimetres

Size		*Inches*	*Centimetres*	*Size*		*Inches*	*Centimetres*
Emperor ..	W	72 × 48	183.0 × 121.9	Demy	PC	22½ × 17½	57.1 × 44.4
Antiquarian ..	WD	53 × 31	134.6 × 78.7	Post	W	19 × 15¼	48.2 × 38.7
Double Elephant	WD	40 × 26¾	101.6 × 68.0	Pinched Post ..	W	18½ × 14¾	49.0 × 37.4
Atlas	WD	34 × 26	86.4 × 66.0	Foolscap	WD	16½ × 13¼	41.9 × 33.6
Colombier ..	WD	34½ × 23½	87.6 × 59.7	Pot	W	15 × 12½	38.1 × 31.7
Imperial ..	WDPC	30 × 22	76.2 × 55.9	Short and ⅓ Foolscap	W	22 × 13½	55.9 × 34.2
Elephant ..	WDC	28 × 23	71.1 × 58.4	Short and ½ Foolscap	W	24½ × 13½	62.2 × 34.2
Cartridge	C	26 × 21	66.0 × 53.3	Double Foolscap ..	W	26½ × 16½	67.2 × 41.9
Super Royal ..	WD	27 × 19	68.6 × 48.2	" " ..	PC	27 × 17	68.6 × 43.2
" " ..	P	27½ × 20½	69.8 × 52.1	Double Crown ..	PC	30 × 20	76.2 × 50.8
Royal	WD	24 × 19	61.0 × 48.2	Double Post ..	W	30½ × 19	77.5 × 48.2
"	PC	25 × 20	63.5 × 50.8	" " ..	P	31½ × 19½	80.0 × 49.5
Medium	WD	22 × 17½	55.9 × 44.4	Double Large Post	WP	33 × 21	83.8 × 53.3
"	WP	23 × 18	58.4 × 45.7	Double Demy ..	W	31 × 20	78.7 × 50.8
Large Post ..	W	21 × 16½	53.3 × 41.9	" " ..	P	35 × 22½	88.9 × 57.1
Copy	W	20 × 16	50.8 × 40.6	" " ..	C	35½ × 22½	90.2 × 57.1
Demy	WD	20 × 15½	50.8 × 39.3	Music Demy ..		20 × 15½	50.8 × 39.3

W, signifies Writings; D, Drawings; P, Printings; C, Cartridges

Comparative Weights in Lb. and Kilos. calculated on Basis of 1016 Kilos. to an English Ton

Lb.	*Kilos.*	*Lb.*	*Kilos.*	*Lb.*	*Kilos.*
1	0.454	23	10.433	84	38.100
2	0.908	24	10.886	90	40.822
3	1.361	25	11.340	100	45.358
4	1.815	26	11.793	112	50.800
5	2.268	27	12.247	120	54.429
6	2.722	28	12.700	130	58.964
7	3.175	29	13.154	140	63.500
8	3.629	30	13.608	150	68.036
9	4.083	31	14.061	160	72.572
10	4.536	32	14.515	170	77.108
11	4.990	33	14.967	180	81.643
12	5.443	34	15.422	190	86.179
13	5.897	35	15.875	200	90.715
14	6.350	40	18.143	224	101.600
15	6.804	45	20.411	250	113.393
16	7.258	50	22.679	300	136.072
17	7.711	56	25.400	336	152.400
18	8.165	60	27.215	350	158.750
19	8.618	65	29.483	400	181.429
20	9.072	70	31.750	500	226.786
21	9.525	75	34.018	560	254.000
22	9.979	80	36.286	1120	508.000

Note.—An easy way to find the nominal comparative weight is to multiply the number of pounds by 454, and divide by 1000. The result is number of kilos.

Comparative Weights in Kilos. and Lb. calculated on Basis of 1016 Kilos. to an English Ton

Kilos.	*Lb.*	*Kilos.*	*Lb.*	*Kilos.*	*Lb.*
1	2.205	23	50.709	85	187.401
2	4.409	24	52.913	90	198.425
3	6.614	25	55.118	100	220.472
4	8.819	26	57.323	110	242.520
5	11.024	27	59.527	120	264.567
6	13.228	28	61.732	130	286.614
7	15.433	29	63.937	140	308.661
8	17.638	30	66.142	150	330.709
9	19.842	31	68.346	160	352.756
10	22.047	32	70.551	170	374.803
11	24.252	33	72.756	180	396.850
12	26.457	34	74.960	190	418.898
13	28.661	35	77.165	200	440.945
14	30.866	40	88.189	250	551.181
15	33.071	45	99.212	300	661.417
16	35.276	50	110.236	350	771.654
17	37.480	55	121.260	400	881.890
18	39.685	60	132.283	500	1102.362
19	41.890	65	143.307	600	1322.834
20	44.094	70	154.331	700	1543.307
21	46.299	75	165.354	800	1763.780
22	48.504	80	176.378	900	1984.252

Note.—An easy way to find the nominal comparative weight is to multiply the number of kilos by 1000, and divide by 454. The result is number of pounds.

To calculate the output of a machine:

Multiply the deckle width in inches by the speed in feet per minute; multiply the result by the substance of the paper in double crown (20 × 30) 480's. Divide the result by 400. The resulting figure is the number of pounds per hour.

Example: Deckle=130 inches. Speed=600 feet per minute. Substance=20 lb. double crown 480 sheets.

$$\frac{130 \times 600 \times 20}{400} = 3900 \text{ lb. per hour.}$$

Another method:

To calculate the output of a machine: Multiply weight per ream by speed per hour in inches by width of web in inches, and divide the result by length of sheet multiplied by breadth of sheet and by number of sheets per ream.

$$\frac{\text{Weight per ream} \times \text{speed per hour in inches} \times \text{width of web}}{\text{Length of sheet} \times \text{breadth of sheet} \times \text{sheets per ream}}.$$

Example: Speed, 100 feet per minute. Deckle width, 68 inches. Substance, $16\frac{1}{2} \times 21 = 21$ lb. 500 sheets.

$$\frac{21 \times (100 \times 12 \times 60) \times 68}{16\frac{1}{2} \times 21 \times 500} = 593\tfrac{5}{11} \text{ lb. per hour.}$$

To find equivalent weights of different sizes of sheets: Multiply known ream weight by length and breadth of sheet, the weight of which is required, and divide the result by length and breadth of sheet, the weight of which is known.

$$\frac{\text{Ream weight} \times (\text{length and breadth of sheet of unknown weight})}{\text{Length} \times \text{breadth of sheet of known weight}}.$$

Example: Sheet $20 \times 25 = 25$ lb. per ream.
Find equivalent weight of sheet 20×30:

$$\frac{25 \times (20 \times 30)}{20 \times 25} = 30 \text{ lb.}$$

To find the weight of paper required for a web of a given length, breadth and substance:

Multiply the ream weight by the length of web in inches and by the breadth in inches; divide the result by the number of sheets per ream, multiplied by the length and breadth of sheet.

$$\frac{\text{Ream weight} \times \text{length of web in inches} \times \text{breadth of web in inches}}{\text{Sheets per ream} \times \text{length of sheet} \times \text{breadth of sheet}}.$$

Example: Find the weight of paper required to produce a web 600 yards

long by 30 inches broad, the paper being the substance of 20×30=25 lb. 500 sheets per ream.

$$\frac{25\times(600\times36)\times30}{20\times30\times50}=54 \text{ lb.}$$

To find the substance of paper in a web of given length, breadth and weight in any size of sheet and number of sheets per ream:

Multiply the weight of web by the length, breadth and number of sheets per ream, and divide result by length of web in inches and breadth of web in inches.

$$\frac{\text{Weight of web}\times\text{length of sheet}\times\text{breadth of sheet}\times\text{sheets per ream.}}{\text{Length of web in inches}\times\text{breadth of web in inches}}$$

Example: Find the weight in 20×30—500 sheets of a web 600 yards long and 30 inches wide weighing 54 lb.

$$\frac{54\times500\times20\times30}{(600\times36)\times30}=25 \text{ lb.}$$

To find the weight of a web of paper:

Multiply width of web in inches by yardage, multiply result by substance in double crown (20×30) 480 sheets, divide result by 8000 and the result is the weight of the web in pounds.

Or

Multiply width of web in inches by yardage, multiply result by substance in demy 480's and divide by 5350. The result is the weight of the web in pounds.

To find the cubical contents of any square or rectangular vessel, multiply the length, breadth and depth together.

Example: Find the number of cubic feet in a tank 6 feet long, 4 feet wide and 3 feet deep:

$$6\times4\times3=72 \text{ cubic feet.}$$

To find the number of gallons a tank will hold, proceed as above and multiply the result in cubic feet by 6·2355, this being the number of gallons in 1 cubic foot.

Extending the above example:

$$6\times4\times3\times6{\cdot}2355=448{\cdot}956 \text{ gallons.}$$

To find the weight of water in a tank, proceed as above and multiply the number of gallons by 10 (1 gallon of distilled water weighs 10 lb.).

Extending the above example:

$$6\times4\times3\times6{\cdot}2355\times10=4489{\cdot}56 \text{ lb.}$$

To find the cubical contents of a cylindrical vessel, square the diameter (that is, multiply the diameter by itself), then multiply the result by 3·1416 Divide the result by 4, then multiply by depth.

Example: Find the cubical content of a vessel 4 feet in diameter by 3 feet in depth.

$$\frac{(4\times 4)\times 3{\cdot}1416\times 3}{4}=37{\cdot}6992 \text{ cubic feet.}$$

To find the number of gallons proceed as for a square or rectangular vessel (see previous examples).

To find the nominal comparative number of pounds in kilos: Multiply the number of pounds by 454 and divide by 1000. The result is the number of kilos.

Vice versa: Multiply the number of kilos by 1000 and divide by 454. The result is the number of pounds.

Bleach Liquor.—One cwt. (112 lb.) of dry bleaching powder of 36 per cent strength produces approximately:

250 gallons of 5° Tw. liquor.
208 " 6° "
178 " 7° "

CYLINDRICAL TANKS: DIAMETERS, CIRCUMFERENCES, AREAS AND CAPACITIES

Diameter		*Circumference*	*Area*	*Capacity at 1-Foot Depth*	*Diameter*		*Circumference*	*Area*	*Capacity at 1-Foot Depth*
Ft.	In.	Ft.	Sq. Ft.	Gallons	Ft.	In.	Ft.	Sq. Ft.	Gallons
1	0	3.14	0.78	4.8	9	6	29.84	70.88	441.7
1	3	3.92	1.22	7.6	10	0	31.41	78.53	489.4
1	6	4.71	1.76	11.0	11	0	34.55	95.03	592.2
1	9	5.49	2.40	15.0	12	0	37.69	113.09	704.8
2	0	6.28	3.14	19.5	13	0	40.84	132.73	829.5
2	3	7.06	3.97	24.7	14	0	43.98	153.93	959.3
2	6	7.85	4.90	30.6	15	0	47.12	176.71	1101.3
2	9	8.63	5.93	37.0	16	0	50.26	201.06	1253.0
3	0	9.42	7.06	44.0	17	0	53.40	226.98	1414.5
3	3	10.21	8.29	51.7	18	0	56.54	254.46	1585.8
3	6	11.00	9.62	59.9	19	0	59.69	283.52	1766.9
3	9	11.78	11.04	68.8	20	0	62.83	314.15	1957.8
4	0	12.56	12.56	78.3	21	0	65.97	346.36	2158.5
4	3	13.35	14.18	88.4	22	0	69.11	380.13	2369.0
4	6	14.13	15.90	99.1	23	0	72.25	415.47	2589.2
4	9	14.92	17.72	110.4	24	0	75.39	452.38	2819.3
5	0	15.70	19.63	122.3	25	0	78.53	490.87	3059.1
5	3	16.49	21.64	134.9	26	0	81.68	530.92	3308.8
5	6	17.27	23.75	148.0	27	0	84.82	572.56	3568.1
5	9	18.06	25.96	161.8	28	0	87.96	615.75	3837.4
6	0	18.84	28.27	176.2	29	0	91.10	660.52	4113.7
6	6	20.42	33.18	206.8	30	0	94.24	706.86	4402.3
7	0	21.99	38.48	239.8	35	0	109.95	962.11	5992.0
7	6	23.56	44.17	275.3	40	0	125.66	1256.63	7826.3
8	0	25.13	50.26	313.2	45	0	141.37	1590.43	9905.2
8	6	26.70	56.74	353.6	50	0	157.08	1963.50	12228.6
9	0	28.27	63.61	396.4					

APPENDIX OF TABLES

USEFUL EQUIVALENTS

IMPERIAL

1 inch = 25.4 mm.
1 foot = 30.480 cm.
1 yard = 0.9144 m.
1 furlong = 0.2011 km.
1 mile = 1.6093 km.

1 sq. in. = 6.4516 sq. cm.
1 sq. ft. = 0.0929 sq. m.
1 sq. yd. = 0.8361 sq. m.
1 acre (4,840 sq. yds.) = 4046.87 sq. m.
1 sq. mile = 259.000 hectares

1 cu. in. = 16.3872 cm.^{3}
1 cu. ft. = 0.0283 m.^{3}
1 cu. yd. = 0.7645 m.^{3}

1 pint = 0.5682 litre
1 quart = 1.1364 litres
1 gallon = 4.5459 litres (277.419 cu. in.)

1 grain = 0.0648 gramme
1 dram = 1.772 grammes
1 oz. = 28.349 grammes
1 lb. (7000 grains) = 0.4536 kg.
1 cwt. = 50.80 kg.
1 ton = 1.016 tonnes

1 h.p. (33,000 ft.-lb. per min.) = 745.9 joules per sec.
1 ft.-lb. (13,825.5 gm. cm.) = 1.3562 joules
1 h.p. hr. (1,980,000 ft.-lb.) = 2,685,443 joules
1 watt-hr. (2654.31 ft.-lb.) = 3600 joules per sec.

METRIC

	In.	*Ft.*
1 millimetre	= 0.0393	= p.0032
1 centimetre	= 0.3937	= 0.0328
1 decimetre	= 3.9370	= 0.3280
1 metre	= 39.3701	= 3.2808
1 kilometre	= 0.62137 ml.	= 3280.8

1 sq. millimetre = 0.0015 sq. in.
1 sq. centimetre = 0.1550 sq. in.
1 sq. metre = 1.1959 sq. yds. (10.7639 sq. ft.)
1 are = 119.59 sq. yds.
1 hectare = 2.471 acres

1 cu. centimetre = 0.0610 cu. in.
1 cubic metre (Stere) = 35.3145 cu. ft. (1.3079 cu. yds.)

1 cu. centimetre = 0.0338 fluid oz. (0.2705 fluid dram)
1 litre (1000 c.c.) = 0.220 gal.
1 cu. metre (1000 litres) = 220.083 gals.

1 milligramme = 0.0154 grain
1 centigramme = 0.1543 grain
1 gramme = 15.4323 grains
1 kilogramme = 2.2046 lb.
1 quintal = 1.9684 cwt.
1 tonne = 2204.62 lb. (0.9842 tons)

1 joule = 0.7373 ft.-lb.
1 joule per sec. (1 watt) = 0.00134 h.p.
1 metric h.p. = 0.9863 h.p.
1 metric h.p. hr. = 1,952,910 ft.-lb.
1 calorie or heat unit = amount of heat required to raise the temperature of 1 gramme of water 1 degree centigrade.

	Reciprocal
1 lb. per sq. in. = 0.0703 kg. per sq. cm.	14.2234
1 lb. per sq. ft. = 4.882 kg. per sq. m.	0.2048
1 grain per gal. = 0.0142 gramme per litre	70.1160
1 lb. per 1000 gals. = 0.1 kg. per m.^{3}	10.0
1 Imp. gal. = 277.419 cu. in.	0.0036
1 Imp. gal. = 0.1605 cu. ft.	6.2278
1 Imp. gal. = 1.2003 U.S. gals.	0.8330
1 cu. ft. water = 6.2278 Imp. gals.	0.1606
1 cu. ft. water = 62.2786 lb.	0.0160
1 inch rainfall = 22,600 gals. per acre	
1 gal. per sq. ft. = 48.895 litres per sq. metre	0.0204
1 gal. per sq. ft. hr. = 1.17 cu. metres per sq. metre per day	0.8550
1 gal. per sq. ft. hr. = 1.92 vertical in. per hour	0.5200
1 gal. per sq. ft. hr. = 1,045,000 gals. per acre per day	
1,000,000 gals. per acre per day = 0.96 gal. per sq. ft. per hour	
1,000,000 gals. per acre per day = 1.84 vertical in. per hour.	

Heads of Water and Corresponding Pressures

Head in Feet	*Pressure Lbs. per Sq. In.*	*Head in Feet*	*Pressure Lbs. per Sq. In.*	*Head in Feet*	*Pressure Lbs. per Sq. In.*	*Head in Feet*	*Pressure Lbs. per Sq. In.*
1	0.4335	2.3067	1	50	21.6753	80.7369	35
1½	0.6502	4.6135	2	75	32.5130	92.2707	40
2	0.8670	6.9203	3	100	43.3507	103.8046	45
2½	1.0837	9.2271	4	125	54.1884	115.3384	50
3	1.3005	11.5388	5	150	65.0260	138.4060	60
4	1.7340	13.8406	6	175	75.8637	161.4736	70
5	2.1675	16.1474	7	200	86.7014	184.5415	80
10	4.3351	18.4541	8	250	108.3767	207.6090	90
15	6.5026	23.0676	10	300	130.0520	230.6768	100
20	8.6701	34.6015	15	350	151.7273	288.3460	125
25	10.8377	46.1354	20	400	173.4028	346.0152	150
30	13.0052	57.6692	25	500	216.7534	403.6844	175
40	17.3403	69.2030	30	600	260.1041	461.3536	200

Degrees of Hardness of Water

	Clark	*German*	*Parts per* 100,000	*Metric (Parts per* 1,000,000)
Clark	1.0	1.25	0.7	0.07
German	0.8	1.0	0.56	0.056
Parts per 100,000	1.42	1.78	1.0	0.1
Metric (mg. per litre or parts per million) ..	14.2	17.8	10.0	1.0

pH Values

Pure distilled water, before exposure to atmosphere, at 22° C. = pH 7.0.
Pure distilled water after exposure to atmosphere = water + carbon dioxide = pH 5.7

pH values over 7.0 denote alkalinity.
pH values under 7.0 denote acidity.

Hydrochloric acid	= pH	1.00
Acetic acid	= ,,	2.86
Pure water	= ,,	7.00
Sodium bicarbonate	= ,,	8.4
Ammonium hydrate	= ,,	11.3
Sodium carbonate	= ,,	11.6
Caustic soda	= ,,	13.1

Specific Gravity of Solutions of Caustic Soda (60° F.=15° C.)

Twaddell	*Grammes per Litre* Na_2O	*Twaddell*	*Grammes per Litre* Na_2O	*Twaddell*	*Grammes per Litre* Na_2O
1	3.7	26	100.5	51	223.4
2	7.5	27	105.0	52	208.9
3	11.3	28	109.6	53	234.4
4	15.1	29	114.1	54	240.0
5	18.8	30	118.6	55	245.5
6	22.6	31	123.2	56	251.0
7	26.4	32	127.7	57	256.6
8	30.2	33	132.2	58	262.1
9	33.9	34	136.8	59	267.6
10	37.7	35	141.3	60	273.2
11	41.6	36	145.8	61	279.3
12	45.5	37	150.4	62	285.4
13	49.4	38	154.9	63	291.5
14	53.2	39	159.4	64	297.7
15	57.1	40	164.0	65	303.8
16	61.0	41	169.4	66	309.9
17	64.9	42	174.7	67	316.0
18	68.8	43	180.1	68	322.2
19	72.7	44	185.5	69	328.3
20	76.5	45	190.9	70	334.4
21	80.4	46	196.3	71	340.8
22	84.3	47	201.7	72	347.2
23	88.2	48	207.0	73	353.6
24	92.1	49	212.4	74	360.1
25	96.0	50	217.8	75	366.5

Note.—To find lb. soda (Na_2O) per cubic foot, divide grammes per litre by 16

BRITISH PAPER TRADE CUSTOMS

FOREWORD

The first codification of Paper Trade Customs as far as existing records show was made in 1899.

These Customs were remodelled and recodified in January, 1906.

In January, 1922, the Customs were again revised and have so operated down to the present date.

In 1934 it was felt that certain further revisions were desirable, and as a result of lengthy negotiations (which were interrupted by the war) the Agreement of all parties has been obtained to the appropriate amendments which are reflected in the Customs recorded herein.

The parties by whom these Customs have been codified and adopted are:—

The British Paper and Board Makers' Association (Incorporated).
The Association of Makers of Coated Papers of Great Britain.
The Association of Makers of Esparto Papers.
The National Association of Packing and Wrapping Paper Makers.
The Royal Hands and Grocery Bags (1928) Association.
The National Association of Paper Merchants.
The British Paper Bag Federation.
The British Paper Box Federation.

PART I. GENERAL CUSTOMS APPLYING TO ALL PAPERS AND BOARDS

1. DELIVERIES

(a) Force Majeure.

In the event of delivery by the Seller or acceptance by the Buyer being wholly or partly prevented or interfered with by Act of God, war, riot, strike, lock-out, civil commotion, fire, drought, flood interruption of transport, Act of Government, destruction or damage of premises, plant or machinery, or any other cause, whether of similar character or not, beyond the control of the party affected, including, in the case of the Buyer, causes affecting the Buyer's customer, the following provisions shall have effect:—

(1) The party affected shall give to the other party immediate notice of the cause preventing or interfering with delivery or acceptance and the extent to which delivery or acceptance is prevented or interfered with and (if possible) the probable duration of the cause of prevention or interference.

(2) During the continuance of the cause of prevention or interference, delivery of the unfulfilled portion of the contract shall be suspended, or, in the case of a partial prevention or interference, reduced until the cause shall have ceased to operate.

(3) Immediately the cause of prevention or interference has ceased to operate, the party concerned shall give notice thereof to the other party, and as soon as practicable thereafter delivery shall be resumed in accordance with the terms of the contract.

(4) If a cause of prevention or interference shall continue for more than two calendar months from the date of commencement of such prevention or interference either party may by notice in writing to the other cancel that portion affected by the delay.

(5) Goods in transit at the time of any notice as aforesaid being given by the Buyer must be accepted by the Buyer notwithstanding such notice.

(*b*) *War.*

If, by reason of war involving any of the Great Powers or any of the Wood Pulp or Esparto Grass producing and/or supplying countries, there shall be an abnormal increase in the cost of paper, the Seller may notify the Buyer of such increase in cost in respect of any unfulfilled portion of a contract and the Buyer shall have the option of agreeing to pay the extra cost or cancelling the remainder of the contract. Any such notification shall be sent by registered letter or other mutually agreed method in writing as between the individual Buyer and Seller, and unless the Buyer within seven days of receiving the Seller's notification of increased cost shall by notice in writing to the Seller elect to pay such increased cost, the Buyer shall be deemed to have elected to cancel the remainder of the contract and it shall be cancelled accordingly.

2. DELAYED DELIVERIES

(*a*) Specification of makings shall be sent to the Seller in reasonable time for delivery on due date.

(*b*) If the paper contracted for be ready for delivery on the specified date and the Buyer does not take delivery when requested by the Seller to do so, it shall be invoiced forthwith and the invoice shall be taken to account.

If the whole of the delivery be not ready, the Seller may invoice such portion of the order as is ready unless a fixed date for delivery of the whole is agreed to between Buyer and Seller.

(*c*) Paper or board stored by the Mill for a period beyond one month after the date of the invoice shall be subject to a minimum rent charge of 1*s.* per ton per week. Insurance shall remain the responsibility of the Mill until delivery is effected. The maximum period for storing by the Mill shall be five months from the date of the invoice, except in the case of Newsprint, when a longer period may be adjusted between the Seller and the Buyer.

(*d*) Except in the case of Newsprint, when the period shall be adjusted between the Seller and the Buyer, where no delivery date is specified the date of final invoice shall in the absence of agreement be six months from date of order, and the above rent charge shall apply as from date of invoice.

3. ARBITRATION

(*a*) All disputes arising under any contract or order shall be settled in the United Kingdom by arbitration under the Arbitration Act, 1889, or any statutory modifications or additions thereto or re-enactments thereof, or in Scotland under the Scottish arbitration statutes.

(*b*) Each party shall appoint an arbiter who, upon question of quality, shall be an expert in paper, and such arbiters shall appoint their umpire before proceeding to reference. No person in the employ of or acting as an agent for either of the parties shall be eligible to act as an arbiter or umpire. If either party fails to appoint an arbiter within ten days of notice in writing from the other party requiring them to do so, the arbiter appointed by the other party shall act for both parties and his award shall bind both parties as if he had been appointed sole arbiter by consent. Should the arbiters and/or umpire decide that the paper is not of the standard ordered, they may authorise rejection of the delivery or they may order acceptance subject to stated allowance, in which latter case they shall also state whether the allowance shall apply to all or part of such portion of the delivery as has been used before their examination, and their decision shall be final and binding on both parties.

(*c*) The costs of any reference shall be borne as the arbiters and umpire may decide.

4. STANDING COMMITTEE

A Standing Committee shall be appointed consisting of six members, with power to the said members to appoint a chairman from among their own number (such chairman to have a

casting vote and to hold the office during the pleasure of the Committee) by mutual agreement jointly by The British Paper and Board Makers' Association (Incorporated) and the National Association of Paper Merchants, three from each Association. In the event of a Bag Maker or Boxmaker being concerned in any question referred to the Standing Committee, then the Committee shall consist, in addition to the six members referred to above, of three members of the British Paper Bag Federation or of the British Paper Box Federation as the case may be. The duty of the Standing Committee shall be to act as a body which shall consider cases requiring interpretation before such matters are finally brought to arbitration. The procedure shall be as follows:—

Any Mill requiring an interpretation of the terms of these Customs shall forward their inquiry to the Secretary of The British Paper and Board Makers' Association (Incorporated), who will remit it to the said Standing Committee. Any Merchant likewise requiring an interpretation of the terms of these Customs shall forward his inquiry to the Secretary of the National Association of Paper Merchants, who will remit it to the said Standing Committee.

Any member of any other organisation parties hereto requiring an interpretation of the terms of these Customs shall forward their inquiry to the Secretary of their Organisations who will remit it to the said Standing Committee.

PART II. PRINTINGS AND WRITINGS

1. SCOPE

Printing, Writing and Envelope papers and boards for printing of all descriptions, whether white, cream, tinted or coloured, and such other papers and boards as are manufactured primarily for printing or writing purposes, including: Newsprint, M.F. Printings, Super-Calendered and similar papers, Offset, Imitation Art, Antique Featherweight, M.G. Litho and other Poster Printings, Cream and Vellum Writings tub-sized or engine-sized, Banks and Bonds, Duplicating papers, Dryings, Filterings, Blottings and other absorbent papers, Drawing and Printing Cartridge and Manillas, Drawing papers, Manifold, Copying, Stereo and Cheque papers, Book-end papers, Pastings, Cover papers, Cloth-lined papers, Writing Tissues, Tracing and Process papers, Bristol Boards, Cards, Ivory Boards, Paste Boards, Pulp Boards and Ticket Boards, but excluding Hand-Made papers, Coated Papers and Coated Boards of all descriptions, Wrappings and Boards for which the relevant Customs are laid down in Parts III, IV, V and VI hereof.

2. CONDITIONS OF SALE

Prices may be agreed:—

(*a*) By weight, whether put up in reams, rolls or any other form.
(*b*) Per ream, or per 1,000 sheets, based upon ordered or nominal weight.

3. TERMS AND DELIVERY

(*a*) Quotations are understood to be net and carriage paid to Buyer's address by cheapest route, unless otherwise stated.

(*b*) Goods invoiced and despatched up to and including the 25th day of the month shall be paid for during the following month.

(*c*) Delivery in the United Kingdom of Great Britain and Northern Ireland shall include delivery at Buyer's Warehouse or that of his consignee.

4. PACKING AND MARKING

(*a*) Wooden Boards, Frames, Cases and Special Centres shall be chargeable at reasonable rates, to be refunded in full when returned within three months, carriage paid in good condition. Ordinary cardboard centres are chargeable but not returnable.

(*b*) The outside of the wrapper of each package must be marked with the ordered size, weight and number of sheets.

5. GRADES

(*a*) Machine-made printings and writings are graded as 'Good' and 'Retree'.

(*b*) 'Retree' is subject to 10 per cent reduction.

6. WRAPPERS

The chargeable weight shall include weight of necessary ream and reel wrappers (not bale wrappers), string and centres (excepting those of wood and/or metal) and wooden plugs.

7. THICKNESS AND WEIGHT VARIATION

Variation shall not exceed 5 per cent either way.

8. CHARGEABLE WEIGHT

(*a*) Ordered weight of sheets and reels (excepting Newsprint) shall be chargeable if actual weight exceeds, or is not more than 2½ per cent under, ordered weight. Actual weight shall be chargeable if more than 2½ per cent under ordered weight.

(*b*) In respect of Newsprint, actual weight of sheets or reels shall be chargeable up to 2½ per cent in excess of ordered weight.

9. SHORT YARDAGE

Claims for short yardage can only be based upon yardage measurements and not from yield.

10. MEASUREMENT VARIATIONS

(*a*) Width of reels shall not vary more than ½ per cent, with a maximum permissible variation of ¼ inch.

(*b*) The variation in measurement of paper in sheets must not exceed ½ per cent either way above or below the ordered measurement, provided always that where ½ per cent is greater than ¼ inch the permissible variation shall be ¼ inch, and that where ½ per cent is less than ⅛ inch the permissible variation shall be ⅛ inch.

(*c*) Where paper is guillotine trimmed, the permissible variation shall be $\frac{1}{16}$ inch.

11. MAKING ORDERS

Making orders shall be deemed to be properly filled if the quantity supplied is within the following limits either way of the quantity ordered:—

1 ton or less	12½ per cent
Over 1 ton and not exceeding 5 tons	7½ "
Over 5 tons and not exceeding 10 tons	5 "
Over 10 tons and not exceeding 20 tons	3¾ "
Over 20 tons	2½ "

The Paper Maker is not required to deliver more than the minimum quantity, but the Buyer must accept the maximum quantity within these tolerances.

12. MATERIALS

Unless it is otherwise expressly stipulated in the order, the Paper Maker shall be free to use his discretion in the selection of materials.

13. DANDY ROLLS AND MOULDS

Any Buyer requiring a special water-mark shall provide the roll or moulds free of charge to the Paper Maker. The Buyer, by agreement with the Paper Maker, may be allowed a credit of 2½ per cent from each invoice for paper made in the Mill from the roll or moulds until the total cost has been refunded when the roll or moulds, but not the design, shall automatically become the property of the Mill. The roll or moulds shall be redeemable by the Buyer within 5 years from the date of the last making of paper from the roll or moulds concerned, upon repayment to the Mill of the total amount of any such allowances. If no such allowances be made, the roll or moulds shall remain the property of the Buyer, who may at any time require delivery thereof. No roll or moulds shall be destroyed until the Buyer has been given in writing the opportunity of redemption.

14. BREAKAGE

In the event of any order which involves a number of sheets less than that comprised in the customary mill package of the paper or board concerned, there shall be charged in respect of the portion of the package so supplied an addition of 10 per cent to the *pro rata* price, such addition to be not less than 6*d.* and not more than (*a*) 1*s.* 6*d.* when the price is 60*s.* 0*d.* or less per 1,000 sheets, or (*b*) 2*s.* 6*d.* when the price exceeds 60*s.* 0*d.* per 1,000 sheets.

15. CLAIMS

(*a*) (1) Claims on any ground whatever must be made in writing within fourteen days after delivery, but this is not to operate in cases where any defect is not revealed by normal examination of the outturn sheets or by reasonable examination of the paper on arrival.

(2) The Paper Maker shall not be liable for consequential loss or damage.

(3) In cases where delivery is within the British Isles, at least half the parcel must be available for examination.

(*b*) For export business, six representative outturn sheets shall be supplied with invoice, but the British exporter is entitled to return to the question of quality in cases where his export buyer subsequently reports within fourteen days after delivery, but this time limit is not to operate in cases where any defect is not revealed by normal examination of the outturn sheets.

(*c*) If an order is to be executed by successive deliveries, each delivery shall be treated as a separate contract and differences or disputes about one delivery shall not affect the balance of the contract.

16. GENERAL CLAUSES

The general and other clauses *mutatis mutandis* of the Paper Trade Customs shall also apply to Printings and Writings.

PART III. HAND-MADE PAPERS

1. PROVISION OF MOULDS

Buyers requiring a special water-mark shall provide the mould free of charge to the Paper Maker.

2. DESCRIPTION AND COUNT

A 'Mill Ream', 'Good' or 'Retree' shall contain 472 sheets, consisting of 18 'Inside' quires of 24 sheets each and two 'Outside' quires of 20 sheets each.

'Outside' quires shall be placed one at the top and one at the bottom of the ream.

An 'Inside' ream 'Good' or 'Retree' shall contain 480 sheets made up of 20 'Inside' quires of 24 sheets each.

Paper sold as 'Retree' shall be subject to a reduction of 10 per cent from the price of 'Good' paper and no more.

Paper sold as 'Outsides' shall be subject to a reduction of 50 per cent from the price of 'Good' paper and no more.

3. SPECIAL MAKINGS

For makings of hand-made papers of special size, substance, tint, water-mark, etc., an order shall be deemed to be properly filled if the quantity supplied is within the following limits either way of the quantity ordered:—

Orders not exceeding 10 cwt.	10 per cent
Orders over 10 cwt. and not exceeding 15 cwt. . .	7½ "
Orders over 15 cwt.	5 "

The above percentages shall apply to whole makings and not to the final instalments of makings only.

The overmaking in all cases shall include 'Retree' and 'Outsides'.

4. BREAKAGE CHARGES

Orders requiring the breakage of a mill package shall be subject to an additional charge. Such additional charge may, however, be waived at the option of the Mill where the quantity ordered includes at least one complete package of the same sort.

5. GENERAL CLAUSES

The general and other clauses *mutatis mutandis* of the Paper Trade Customs shall also apply to Hand-Made Papers.

PART IV. COATED PAPERS AND COATED BOARDS

1. CONDITIONS OF SALE

Prices may be agreed:—

(*a*) By weight, whether put up in reams, rolls or any other form.

(*b*) Per ream, per centum, per gross, or per 1,000 sheets or any part thereof.

2. TERMS AND DELIVERY

(*a*) Quotations are understood to be net and carriage paid to Buyer's address, unless otherwise stated.

(*b*) Goods invoiced and despatched up to and including the 25th of the month shall be paid for during the following month.

(*c*) Delivery in the British Isles shall include delivery at Buyer's Warehouse or that of his consignee.

3. PACKING AND MARKING

(*a*) In respect of deliveries within the British Isles, Wooden Boards, Frames and Special (not ordinary cardboard) Centres shall be chargeable at reasonable rates, to be refunded in full when returned within a reasonable time, carriage paid and in good condition. In respect of deliveries outside the British Isles, appropriate extras shall be chargeable according to the type of packing required. Ordinary cardboard centres are chargeable but not returnable.

(*b*) The outside of the wrapper of each package must be marked with the ordered size, weight and number of sheets.

4. GRADES

Coated Papers and Boards shall be graded as 'Good' and 'Retree'.

'Retree' shall be subject to 10 per cent reduction.

5. WRAPPERS

The chargeable weight shall include weight of necessary ream and reel wrappers (not bale wrappers), string and centres (excepting those of wood and/or metal) and wooden plugs.

6. THICKNESS AND WEIGHT VARIATION

Variation shall not exceed 5 per cent either way.

7. CHARGEABLE WEIGHT

Ordered weight of sheets and reels shall be chargeable if actual weight exceeds, or is not more than 2½ per cent under, ordered weight. Actual weight shall be chargeable if more than 2½ per cent under ordered weight.

8. SHORT YARDAGE

Claims for short yardage can only be based upon yardage measurements and not from yield.

9. MEASUREMENT VARIATIONS

(*a*) Width of reels shall not vary more than ½ per cent with a maximum permissible variation of ¼ inch.

(*b*) The variation in measurement of paper in sheets must not exceed ½ per cent either way above or below the ordered measurement, provided always that where ½ per cent is greater than ¼ inch the permissible variation shall be ¼ inch and that where ½ per cent is less than ⅛ inch, the permissible variation shall be ⅛ inch.

(*c*) Where paper is guillotine trimmed, the permissible variation shall be $\frac{1}{16}$ inch.

10. MAKING ORDERS

The minimum quantity for a making order of Coated Paper for which the body paper is to be specially made or procured shall be 25 cwt. finished weight. Making orders shall be deemed to be properly filled if the quantity supplied is within the following limits either way of the quantity ordered:—

25 cwt. or less	12½ per cent
Over 25 cwt. and not exceeding 5 tons	7½ "
Over 5 tons and not exceeding 10 tons	5 "
Over 10 tons and not exceeding 20 tons	3¾ "
Over 20 tons	2½ "

11. MATERIALS

Unless it is otherwise expressly stipulated in the order, the Paper Maker shall be free to use his discretion in the selection of materials.

12. BREAKAGE

In the case of any order which involves a number of sheets less than that comprised in the customary mill package of the paper or board concerned, there shall be charged in respect of the portion of the package so supplied an addition of 10 per cent to the *pro rata* price, such addition to be not less than 6*d*. and not more than (*a*) 1*s*. 6*d*. when the price is 60*s*. 0*d*. or less per 1,000 sheets, or (*b*) 2*s*. 6*d*. when the price exceeds 60*s*. 0*d*. per 1,000 sheets.

13. CLAIMS

(*a*) Claims on any ground whatever must be made in writing within fourteen days after delivery, but this is not to operate in cases where any defect is not revealed by normal examination of the outturn sheets or by reasonable examination of the paper on arrival. The Paper Maker shall not be liable for consequential loss or damage. In cases where delivery is within the British Isles, at least half the parcel must be available for examination.

(*b*) For export business, six representative outturn sheets shall be supplied with invoice, but the British exporter is entitled to return to the question of quality in cases where his export buyer subsequently reports within fourteen days after delivery, but this time limit is not to operate in cases where any defect is not revealed by normal examination of the outturn sheets.

(*c*) If an order is to be executed by successive deliveries, each delivery shall be treated as a separate contract and differences or disputes about one delivery shall not affect the balance of the contract.

14. GENERAL CLAUSES

The general and other clauses *mutatis mutandis* of the Paper Trade Customs shall also apply to Coated Papers and Coated Boards.

PART V. WRAPPING PAPERS

1. SCOPE

Wrapping or packing papers of all descriptions and such other papers as are manufactured primarily for wrapping or packing purposes, including *inter alia* Caps, Kraft, machine-glazed and glazed Sulphites, Casings, Common Browns, Drabs, Yellows, Buffs, G.I.P., Tea, Sugar and other Food Wrapping Papers.

2. CONDITIONS OF SALE

Prices may be agreed:—

(*a*) By weight, whether put up in reams, rolls or any other form.

(*b*) Per ream, or per 1,000 sheets, based upon ordered weight.

3. TERMS AND DELIVERY

(*a*) Quotations or orders are understood to be net and carriage paid to Buyer's address.

(*b*) Goods invoiced and despatched up to the 25th of the month shall be paid for during the following month.

(*c*) Delivery in the United Kingdom of Great Britain and Northern Ireland shall include delivery at Buyer's Warehouse or that of his consignee.

4. PACKING AND MARKING

(*a*) Wooden Boards, Frames, Cases and Special (not ordinary cardboard) Centres shall be chargeable at reasonable rates, to be refunded in full when returned within a reasonable time, carriage paid and in good condition. Ordinary cardboard centres are chargeable but not returnable.

(*b*) The outside of the wrapper of each package shall be marked with the ordered size, weight and number of sheets.

5. WRAPPERS

The chargeable weight shall include weight of necessary ream and reel wrappers (not bale wrappers), string and centres (excepting those of wood and/or metal) and wooden plugs.

6. WEIGHT (SUBSTANCE) VARIATIONS

Average variation shall not exceed 5 per cent either way.

7. CHARGEABLE WEIGHT

Actual weight of sheets and reels shall be chargeable provided that average variation does not exceed 5 per cent either way.

8. SHORT YARDAGE

Claims for short yardage can only be based upon yardage measurements and not from yield.

9. MEASUREMENT VARIATIONS

(*a*) Width of reels shall not vary more than ½ per cent with a maximum permissible variation of ¼ inch.

(*b*) The variation in measurement of paper in sheets must not exceed ½ per cent either way above or below the ordered measurement, provided always that where ½ per cent is greater than ¼ inch the permissible variation shall be ¼ inch and that where ½ per cent is less than ⅛ inch, the permissible variation shall be ⅛ inch.

(*c*) Where paper is guillotine trimmed, the permissible variation shall be $\frac{1}{16}$ inch.

10. MAKING ORDERS

Making orders shall be deemed to be properly filled if the quantity supplied is within the following limits either way of the quantity ordered:—

1 ton or less	12½ per cent
Over 1 ton and not exceeding 5 tons	7½ "
Over 5 tons and not exceeding 10 tons	5 "
Over 10 tons and not exceeding 20 tons	3¾ "
Over 20 tons	2½ "

11. MATERIAL

Unless it is otherwise expressly stipulated in the order, the Paper Maker shall be free to use his discretion in the selection of materials.

12. DANDY ROLLS AND MOULDS OR OTHER MARKING DEVICES

Any Buyer requiring a special water-mark shall provide the roll or moulds free of charge to the Paper Maker. The Buyer, by agreement with the Paper Maker, may be allowed a credit of 2½ per cent from each invoice for paper made by the Mill from the roll or moulds until the total cost has been refunded, when the roll or moulds, but not the design, shall automatically become the property of the Mill. The roll or moulds shall be redeemable by the Buyer within 5 years from the date of the last making of paper from the roll or moulds concerned, upon repayment to the Mill of the total amount of any such allowances. If no such allowances be made, the roll or moulds shall remain the property of the Buyer, who may at any time require delivery thereof. No roll or moulds shall be destroyed until the Buyer has been given in writing the opportunity of redemption.

13. BREAKAGE

In the case of any order which involves a number of sheets less than that comprised in the customary mill package of the paper concerned, there shall be charged in respect of the portion of the package so supplied an addition of 10 per cent to the *pro rata* price, such addition to be not less than 6*d.* and not more than

(*a*) 1*s.* 6*d.* when the price is 60*s.* 0*d.* or less per 1,000 sheets, or
(*b*) 2*s.* 6*d.* when the price exceeds 60*s.* 0*d.* per 1,000 sheets.

14. CLAIMS

(*a*) Claims on any ground whatever must be made in writing within fourteen days after delivery, but this is not to operate in cases where any defect is not revealed by normal examination of the outturn sheets, or by reasonable examination of the paper on arrival. The Paper Maker shall not be liable for consequential loss or damage. In cases where delivery is within the British Isles, at least half the parcel must be available for examination.

(*b*) For export business, six representative outturn sheets shall be supplied with invoice, but the British exporter is entitled to return to the question of quality in cases where his export buyer subsequently reports within fourteen days after delivery, but this time limit is not to operate in cases where any defect is not revealed by normal examination of the outturn sheets.

(*c*) If an order is to be executed by successive deliveries, each delivery shall be treated as a separate contract and differences or disputes about one delivery shall not affect the balance of the contract.

15. GENERAL CLAUSES

The general and other clauses *mutatis mutandis* of the Paper Trade Customs shall also apply to Wrapping Papers.

PART VI. CARDBOARD, MILLBOARD AND BOXBOARD

1. SCOPE

There shall be included in this Section the following:—

Cardboard, Millboard and Boxboard of various descriptions (hereinafter referred to as Boards) including Binders Boards, Boxboards, Duplex Boards, Embossed Boards, Fibre Boards, Glazed Boards, Leatherboards, Middles, Millboards, Mill Wrappers, Portmanteau Boards,

Press Boards, Shoe Stiffenings, Silk Boards, Stiffeners, Strawboards, Triplex Boards, Trunk Boards, Woodpulp Boards (but excluding Boards for Printing and Coated Boards, which are covered by Parts II and IV hereof) all of a substance equivalent to more than 90 lb. per 480 sheets of Double Crown measuring 20 inches by 30 inches.

2. CONDITIONS OF SALE

(1) PRICES.—Boards, whether sheets or reels, shall be sold by weight, that is, at a specified price per ton, except in such cases as Buyer and Seller may have specially agreed otherwise.

(2) MEASUREMENTS.—The sizes of sheets or width and diameter of rolls shall be stated in inches, or fractions of an inch, down to $\frac{1}{8}$ inch, except in specially agreed circumstances.

(3) DELIVERY.—Prices shall be understood to include delivery free to Buyer's address, unless otherwise stated. The choice of route and mode of delivery shall be at the discretion of the Seller.

(4) TERMS.—Shall be net and payment due 30 days from invoice date.

3. MATERIALS

Unless it is otherwise expressly stipulated in the order, and agreed, the Board Manufacturer shall be free to use his discretion in the selection of materials.

4. MANUFACTURING VARIATIONS

(1) SUBSTANCE.—Variation of substance shall not exceed 5 per cent either above or below the substance specified.

(2) THICKNESS.—Variation of thickness shall not exceed 5 per cent with a minimum of ·001 inch over or under the specified thickness.

(3) MEASUREMENTS.—The allowable variation in measurement of boards, in sheets or reels, shall be $\frac{1}{2}$ per cent above or below ordered measurements, provided always that where $\frac{1}{2}$ per cent is greater than $\frac{1}{4}$ inch the permissible variation shall be $\frac{1}{4}$ inch, and where $\frac{1}{2}$ per cent is less than $\frac{1}{8}$ inch the permissible variation shall be $\frac{1}{8}$ inch.

In the case of guillotine trimmed sheets and slit reels of width of less than 12 inches, the permissible variation shall be $\frac{1}{16}$ inch.

(4) QUANTITY.—Making orders shall be considered properly executed if the quantity supplied is within the following limits of the quantity ordered:—

10 tons up to and including 15 tons . .	10 per cent	over or	under
Over 15 tons and less than 20 tons . .	7½	,,	,,
20 tons and over	5	,,	,,

Orders below 10 tons to be by arrangement between Mill and Customer.

When orders carry a definite maximum or minimum limitation as to quantity, such as (*a*) 'not less than' or (*b*) 'not more than', the percentage of variation allowable shall be by arrangement between Mill and Customer.

5. PACKING

(1) SHEETS.—The chargeable weight shall include the weight of necessary bundle wrappers (not bale wrappers) and strings where used.

(2) REELS.—Board in reels shall be charged at gross weight inclusive of wrappers, centres and plugs (excluding wood or metal centres), which are not returnable. Ordinary cardboard centres are chargeable but not returnable.

6. DELAYED DELIVERIES

(1) Specification of makings shall be sent to the Seller in reasonable time for delivery to be made.

(2) All 'make and hold' orders shall specify a definite date at which goods shall be charged and invoices shall be taken to account by Buyer.

7. DISSATISFACTION OR COMPLAINT

Complaints on any grounds whatever must be made in writing within fourteen days after delivery, but in cases where any defect is not revealed by reasonable examination of the board on arrival, this period may be extended to thirty days after delivery. The Board Maker shall not be liable for consequential damage or loss.

8. GENERAL CLAUSES

The general and other clauses *mutatis mutandis* of the Paper Trade customs shall also apply to Cardboard, Millboard and Boxboard of various types.

MODEL CENTRE FOR VILLAGE INDUSTRIES, ★ T. KALLUPATTI, MADURAI DT. ★
25 SEP 1957

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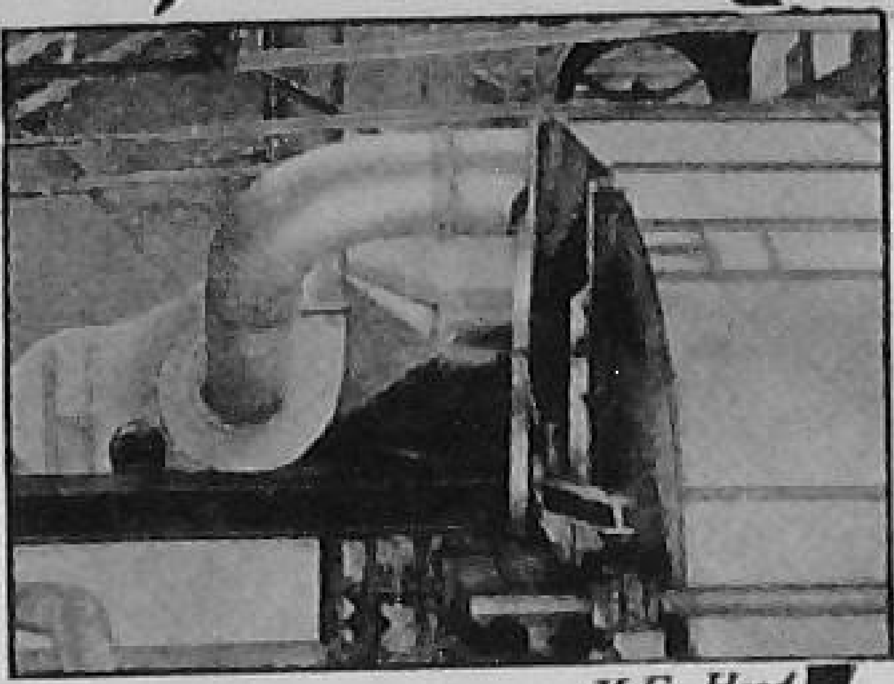

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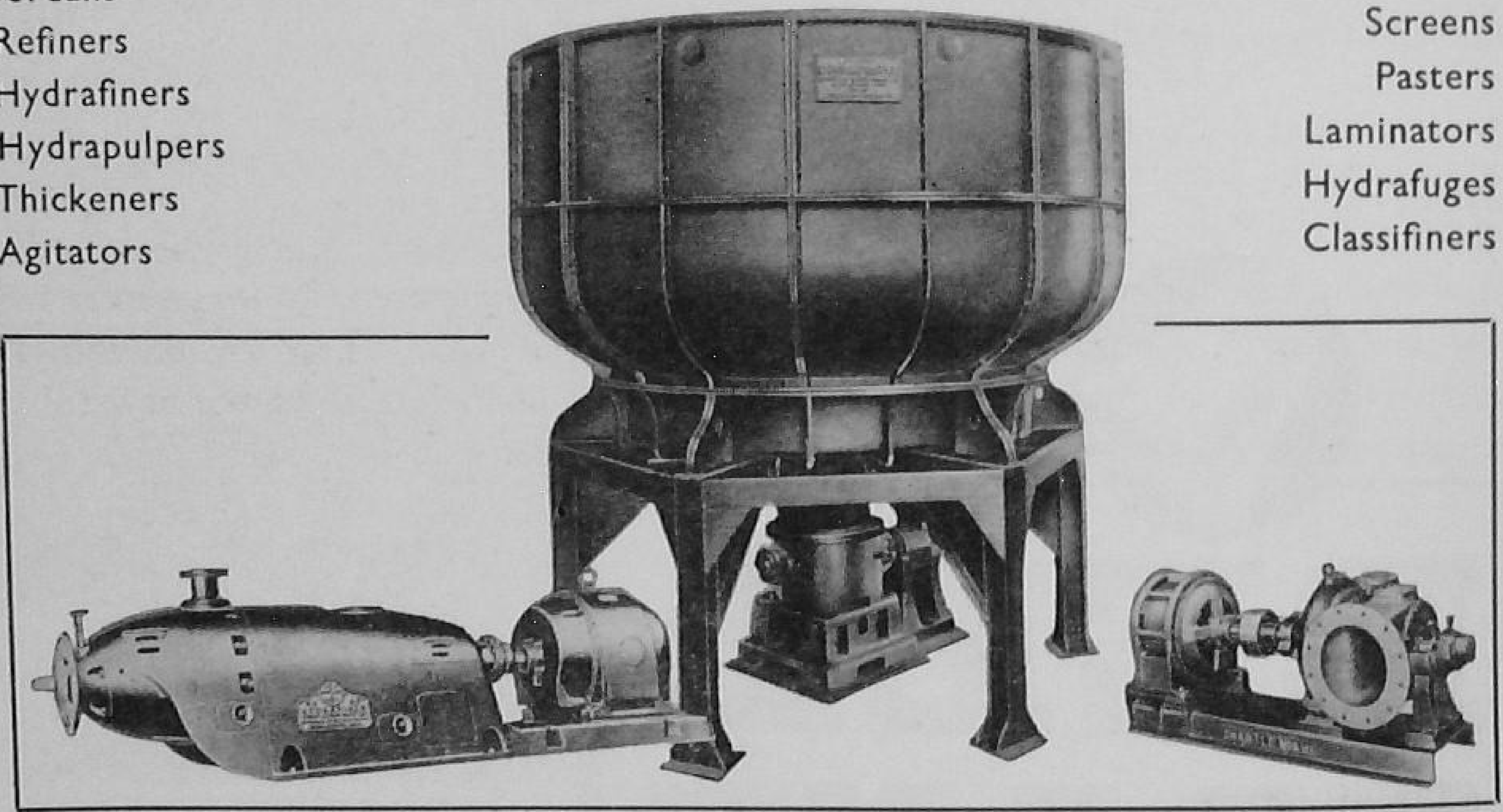

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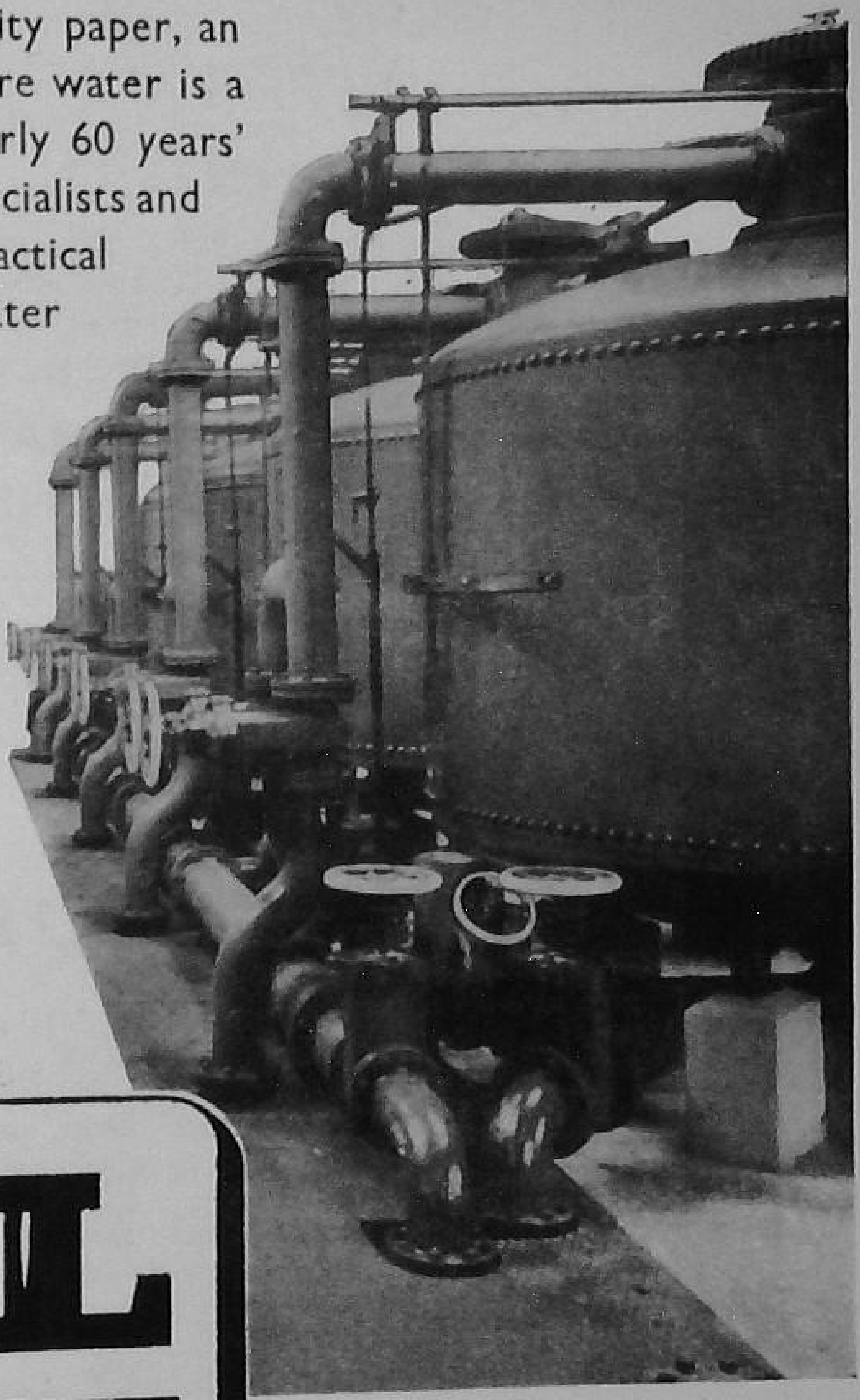

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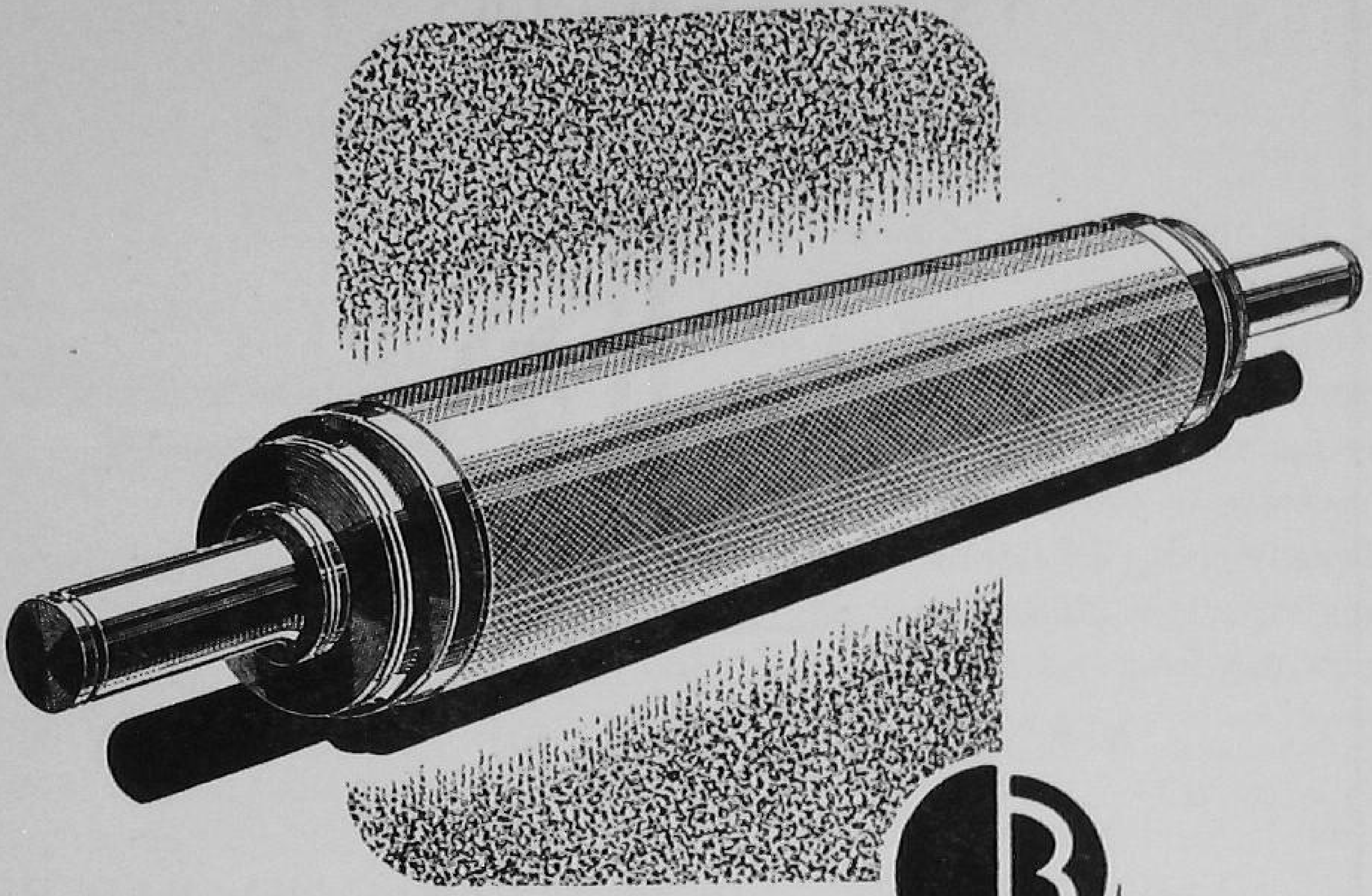

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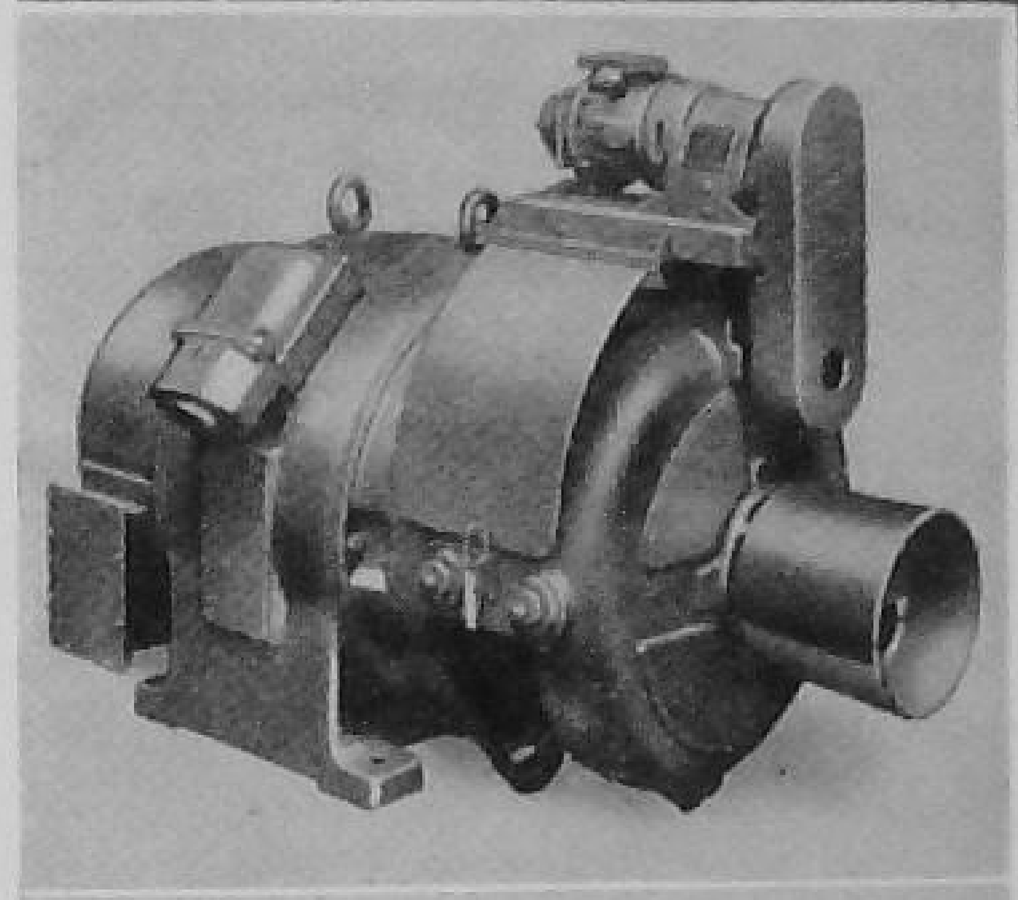

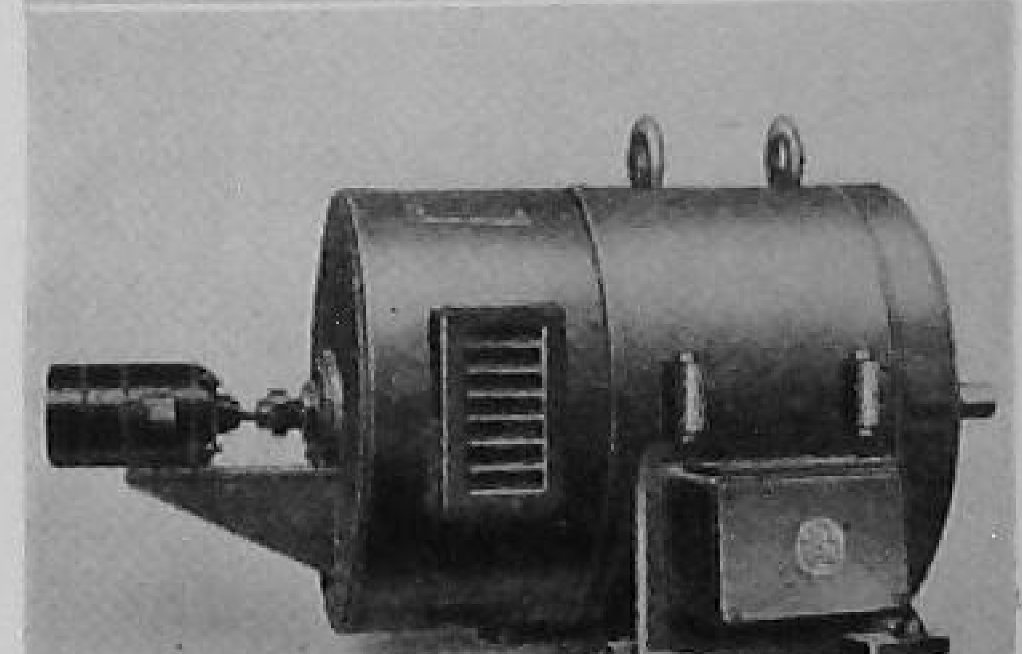

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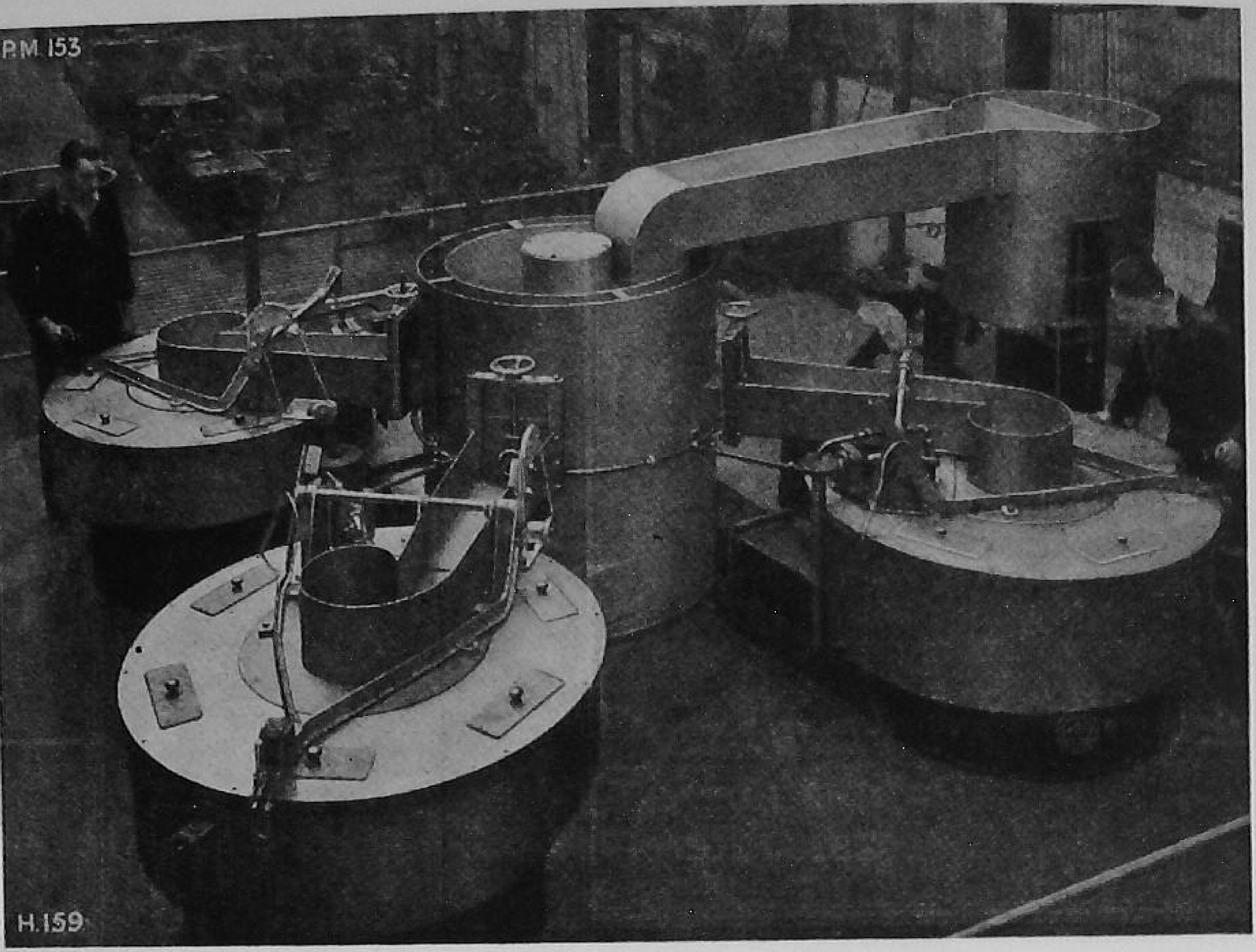

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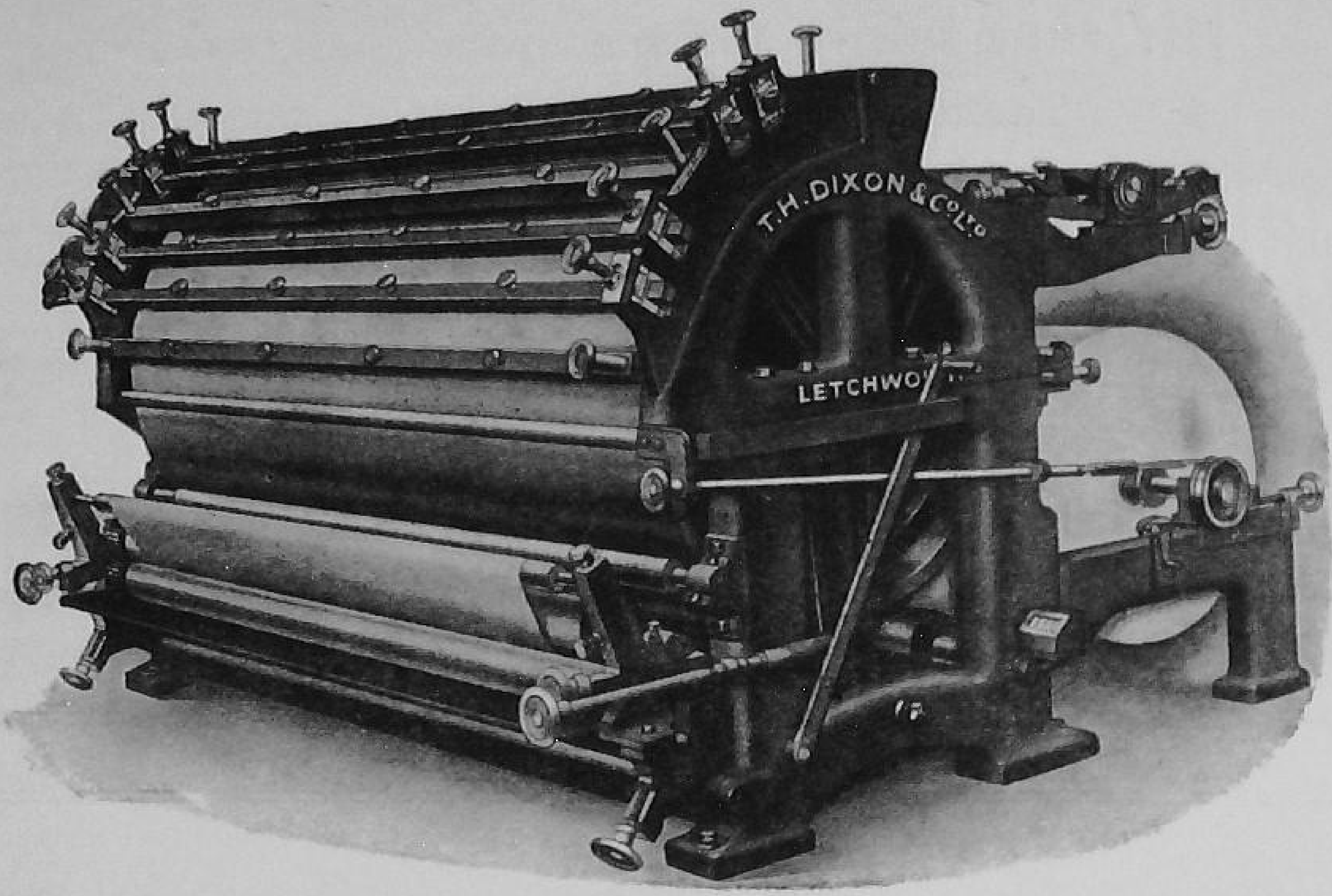

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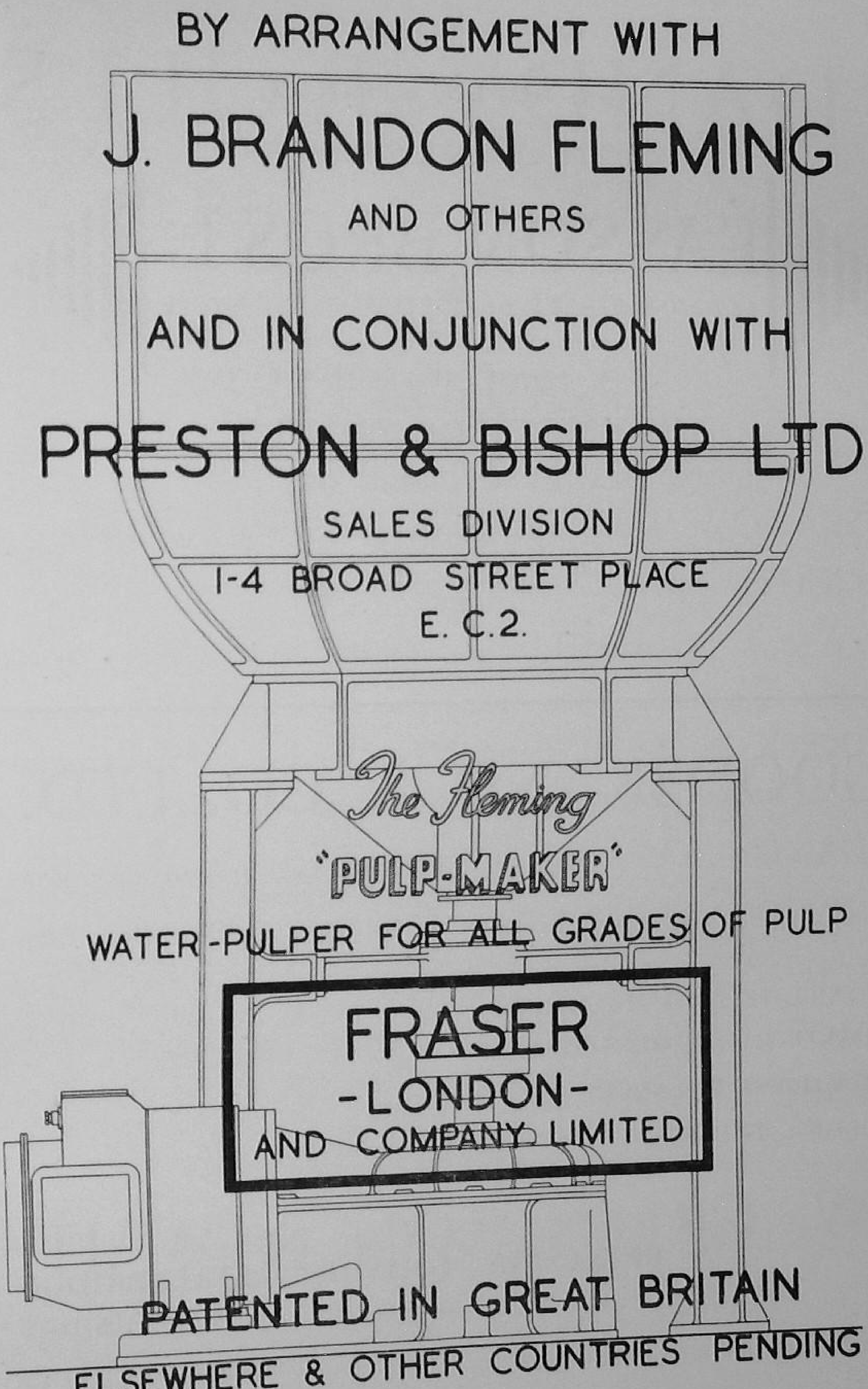
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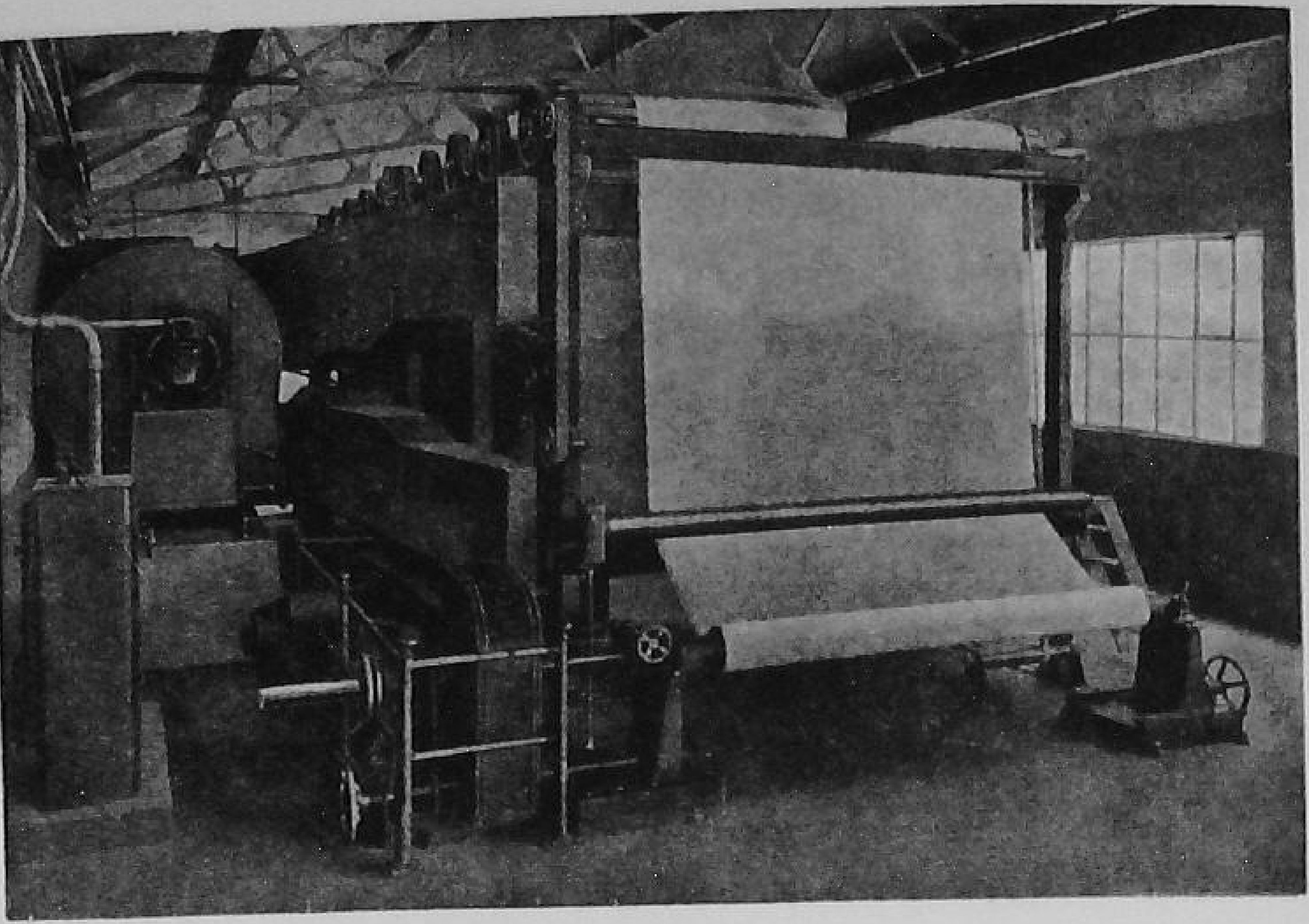

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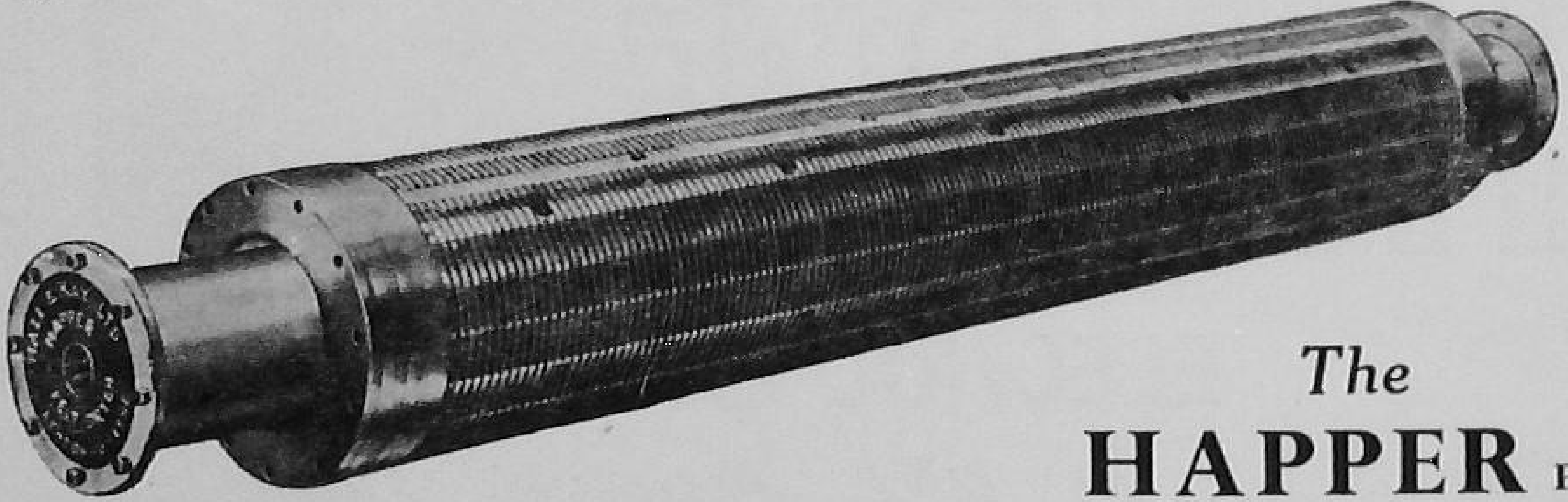

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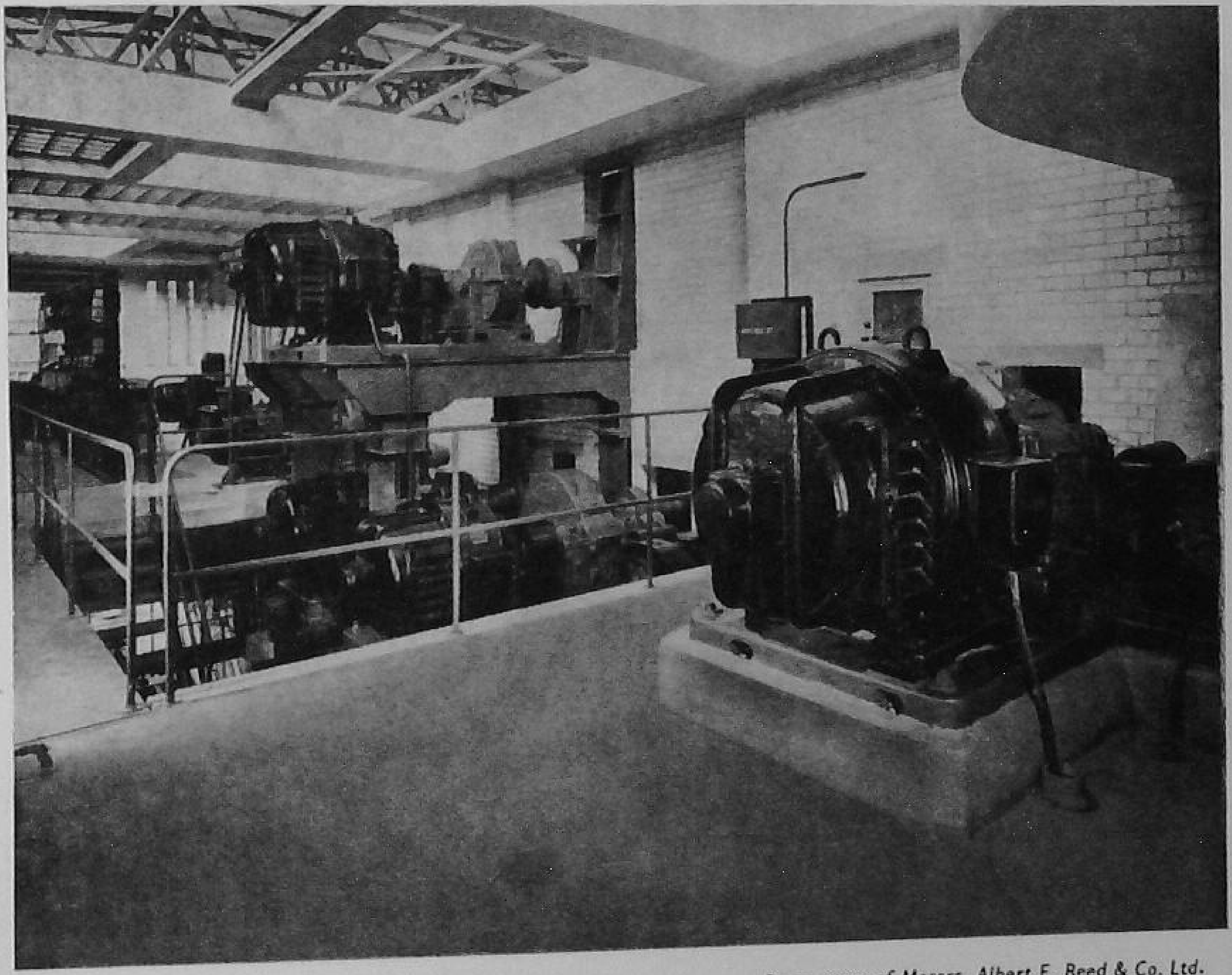

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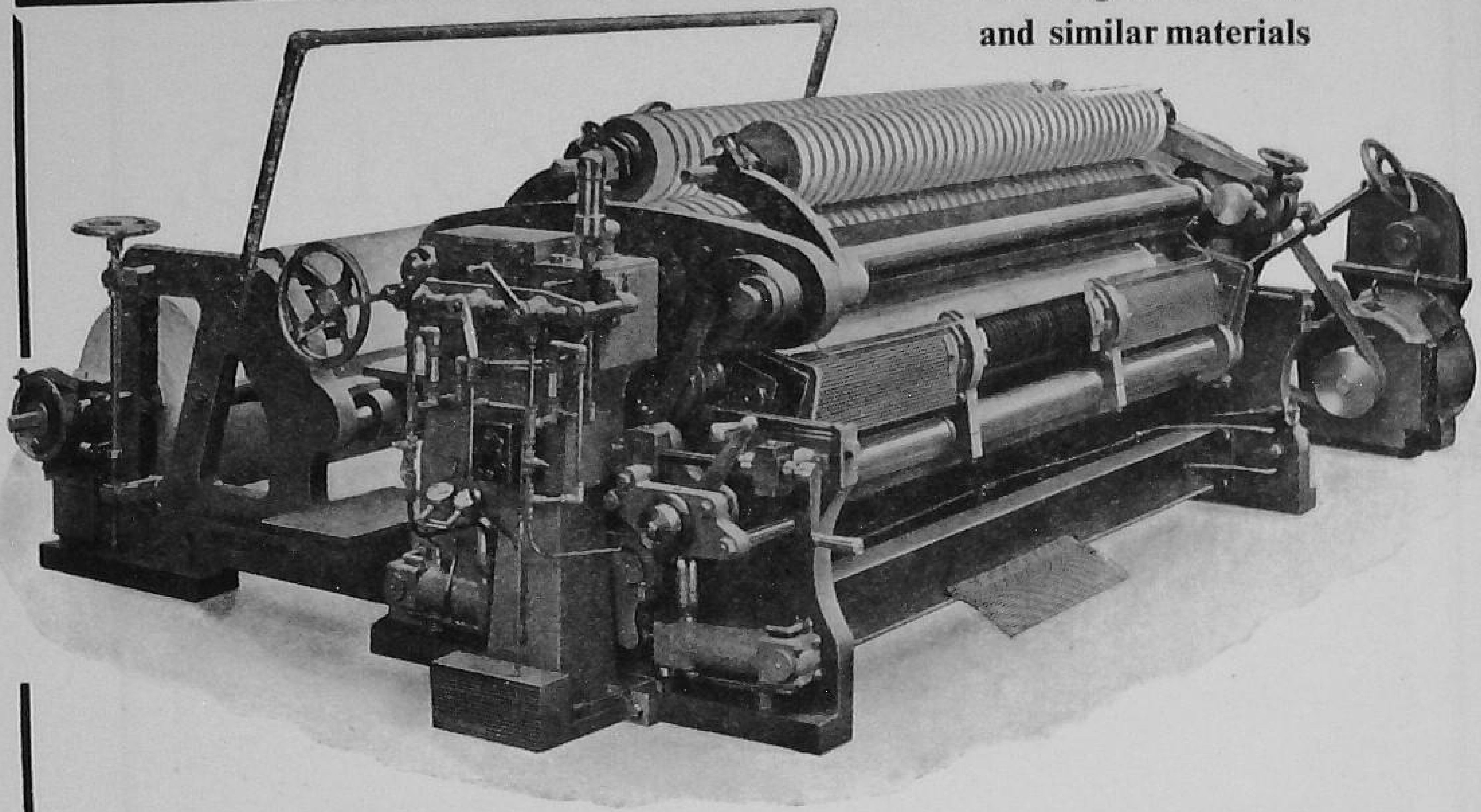

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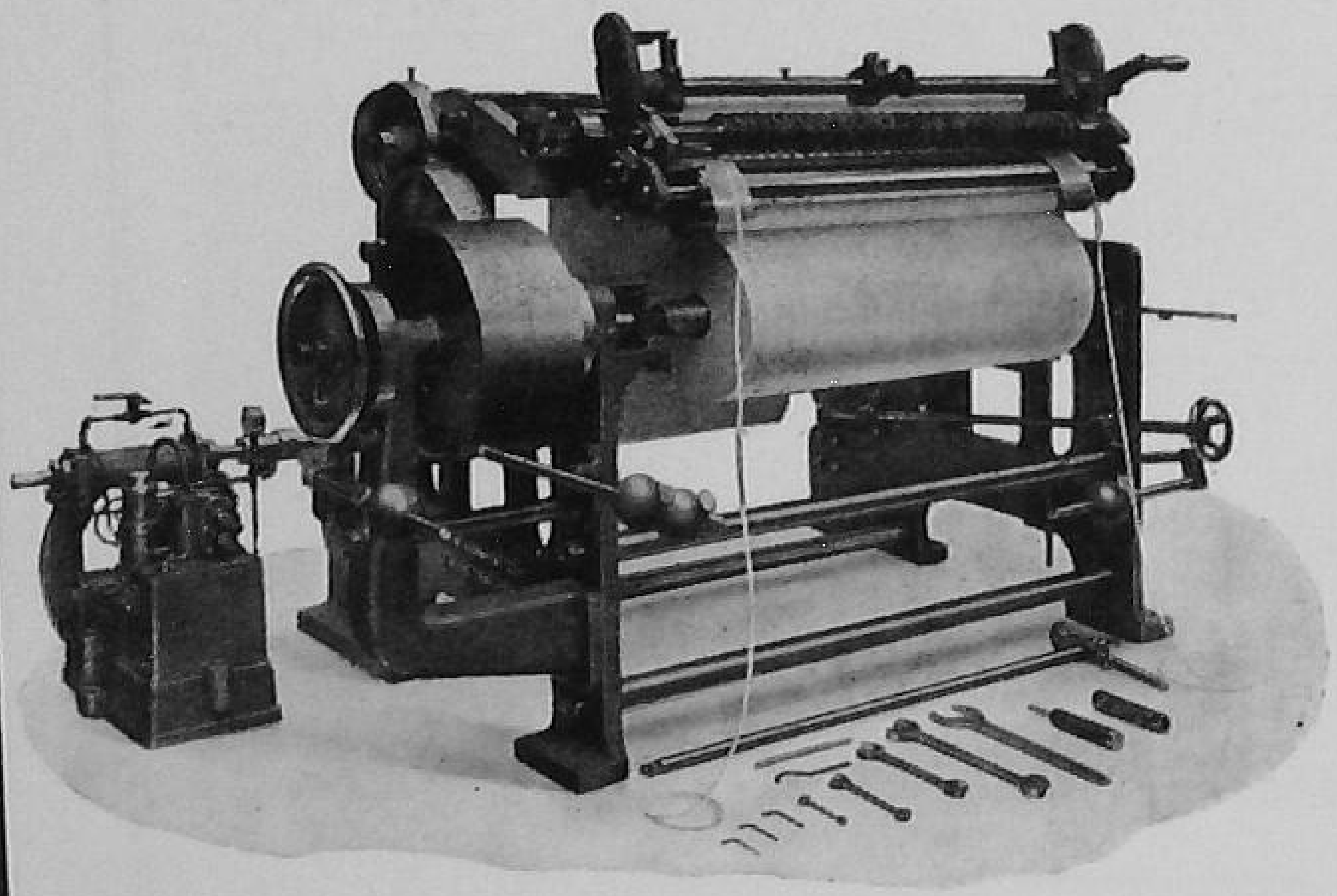

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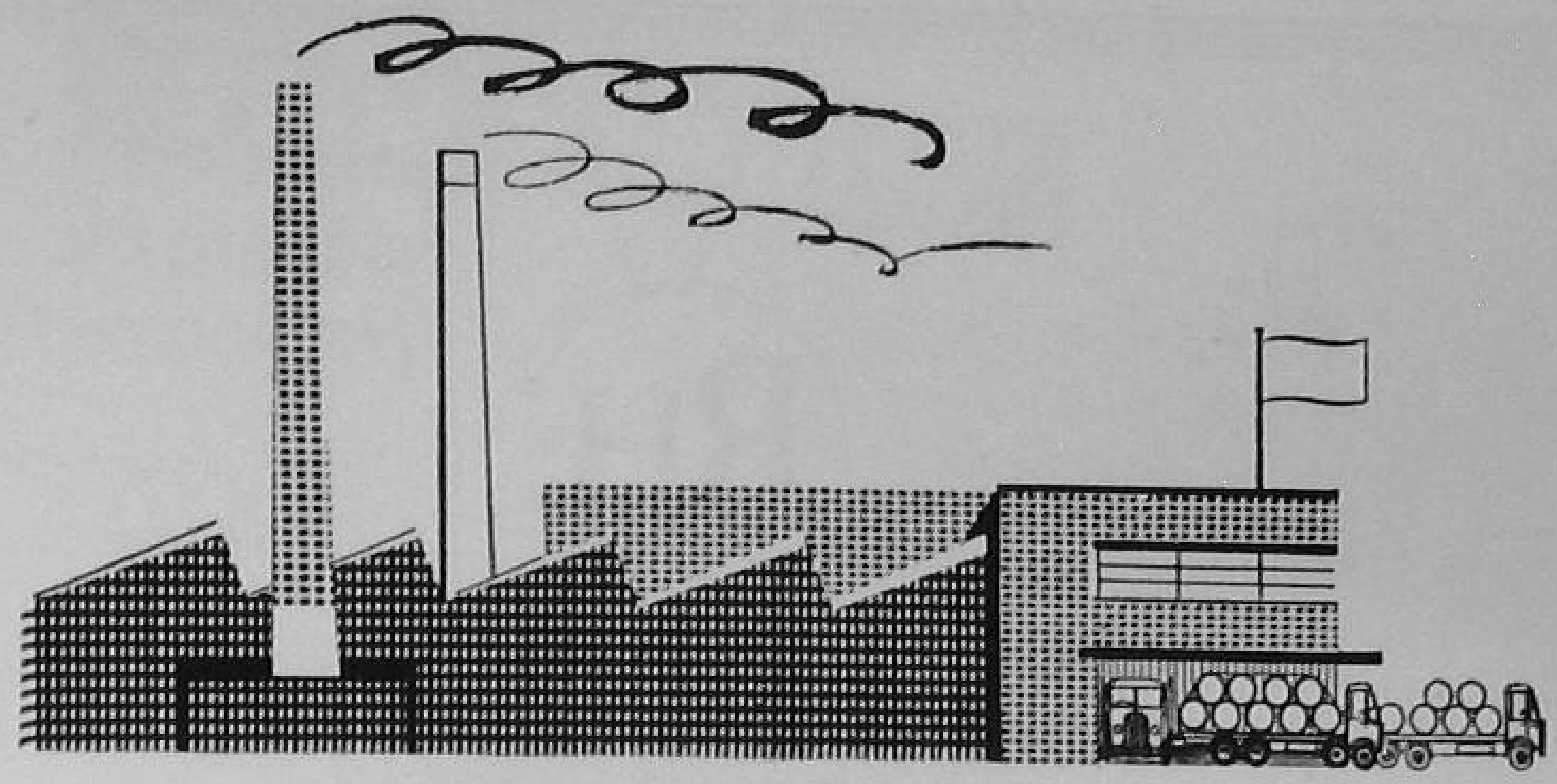

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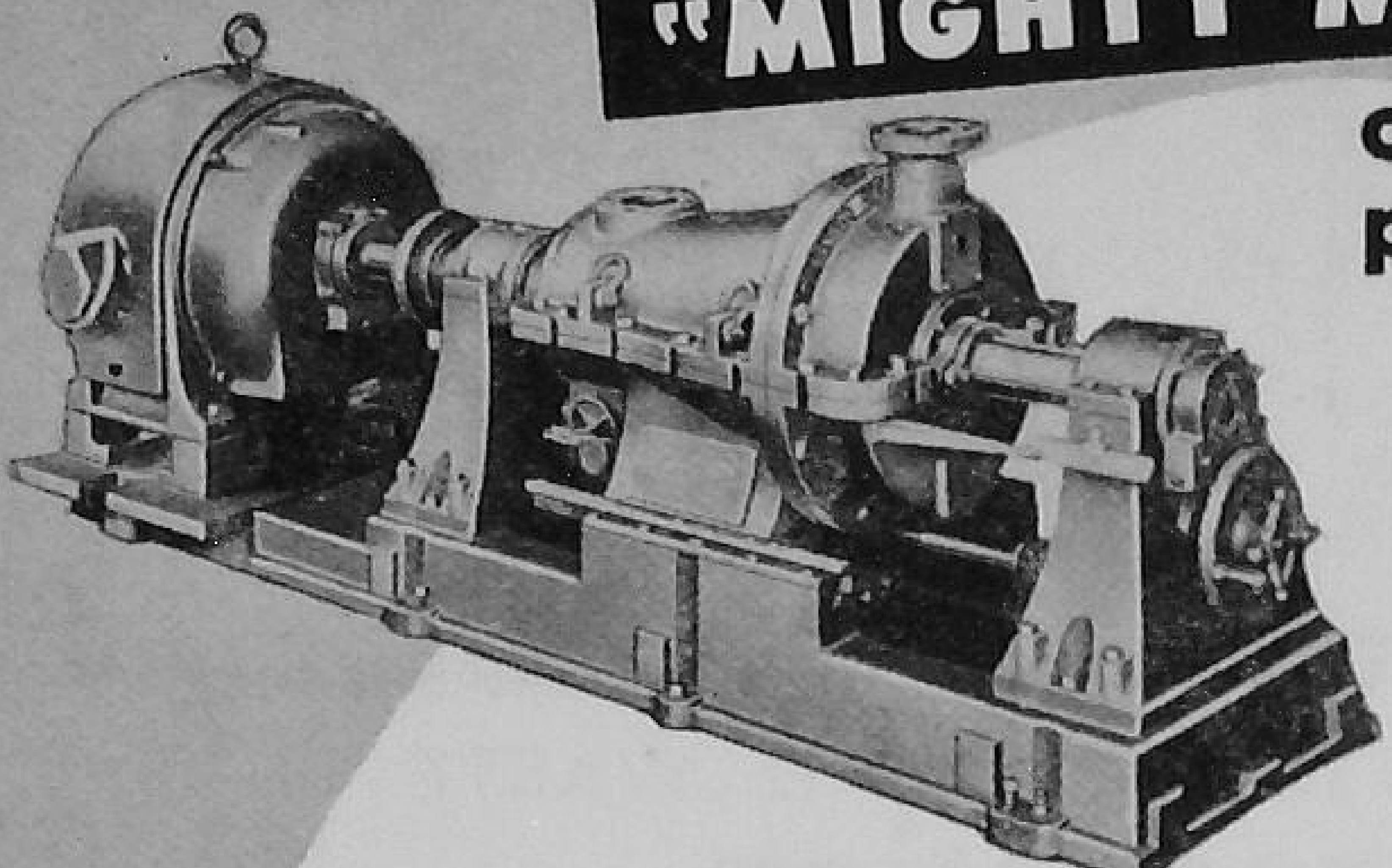

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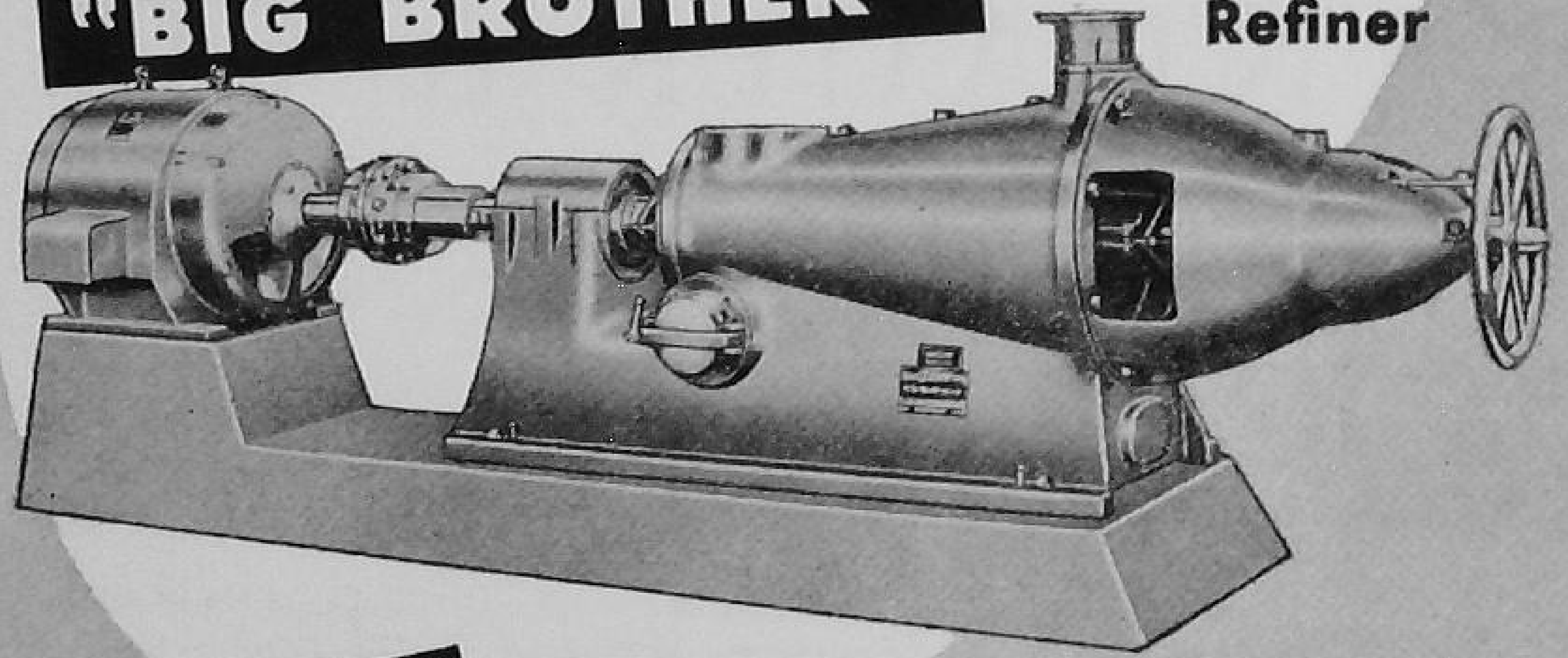

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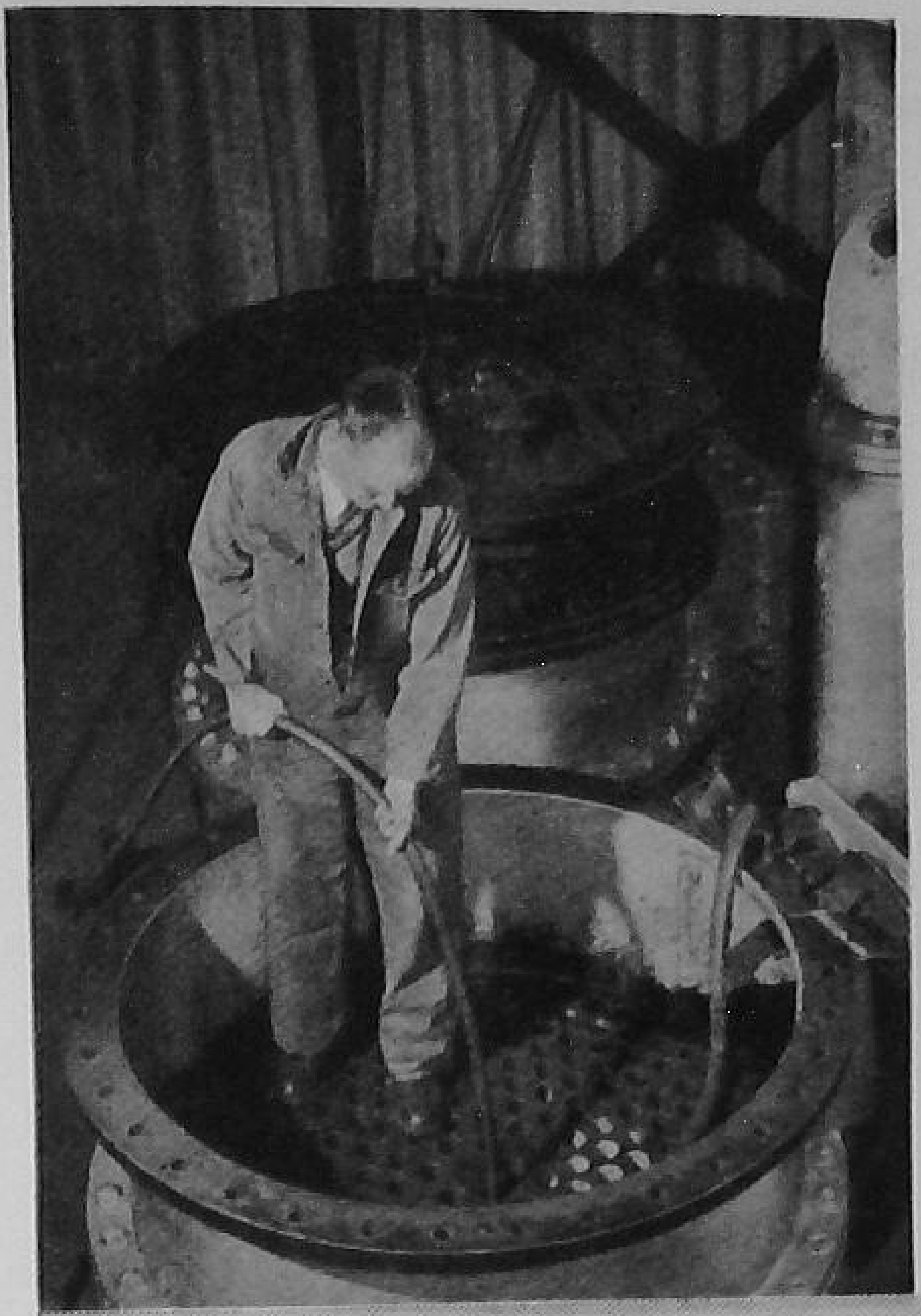

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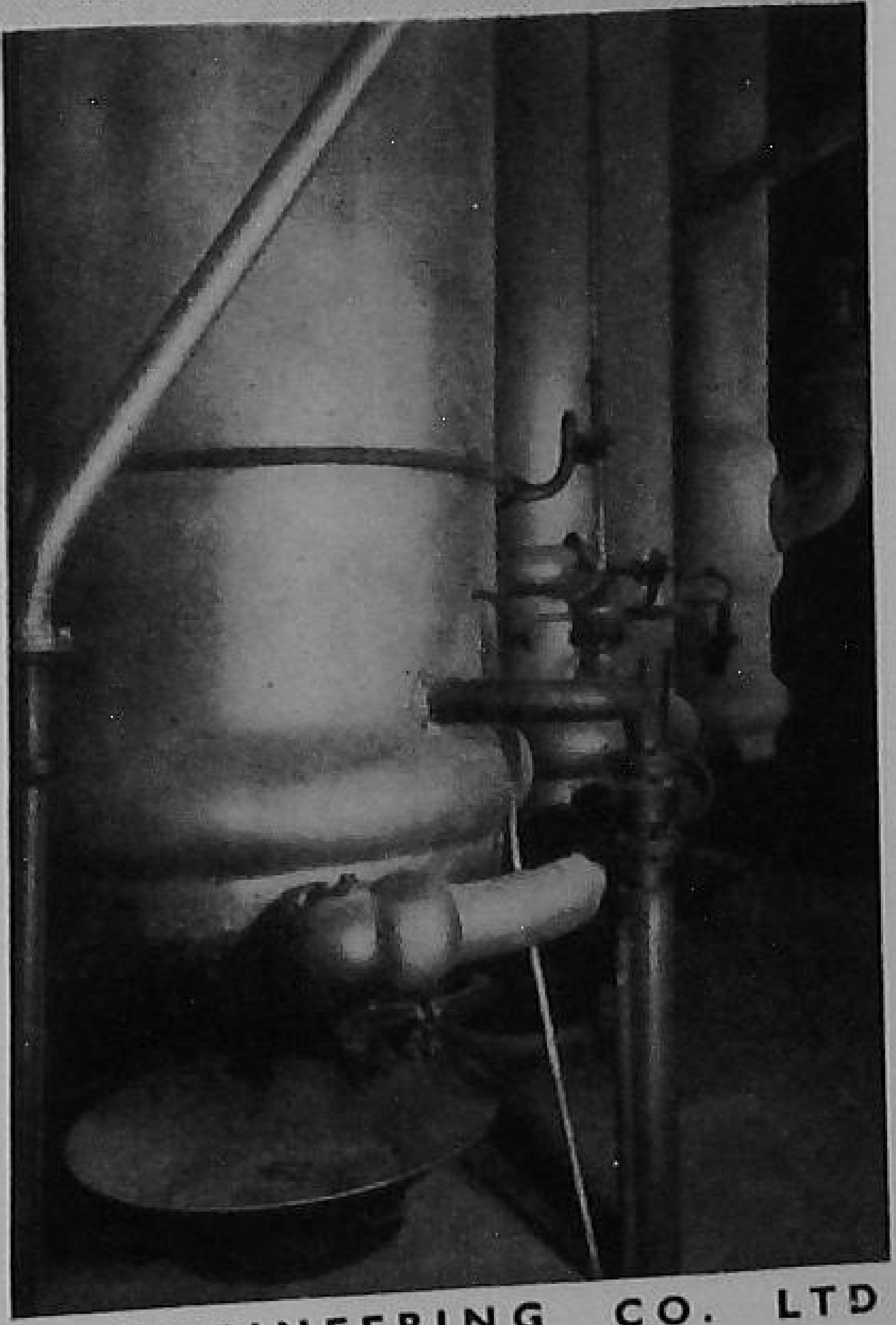

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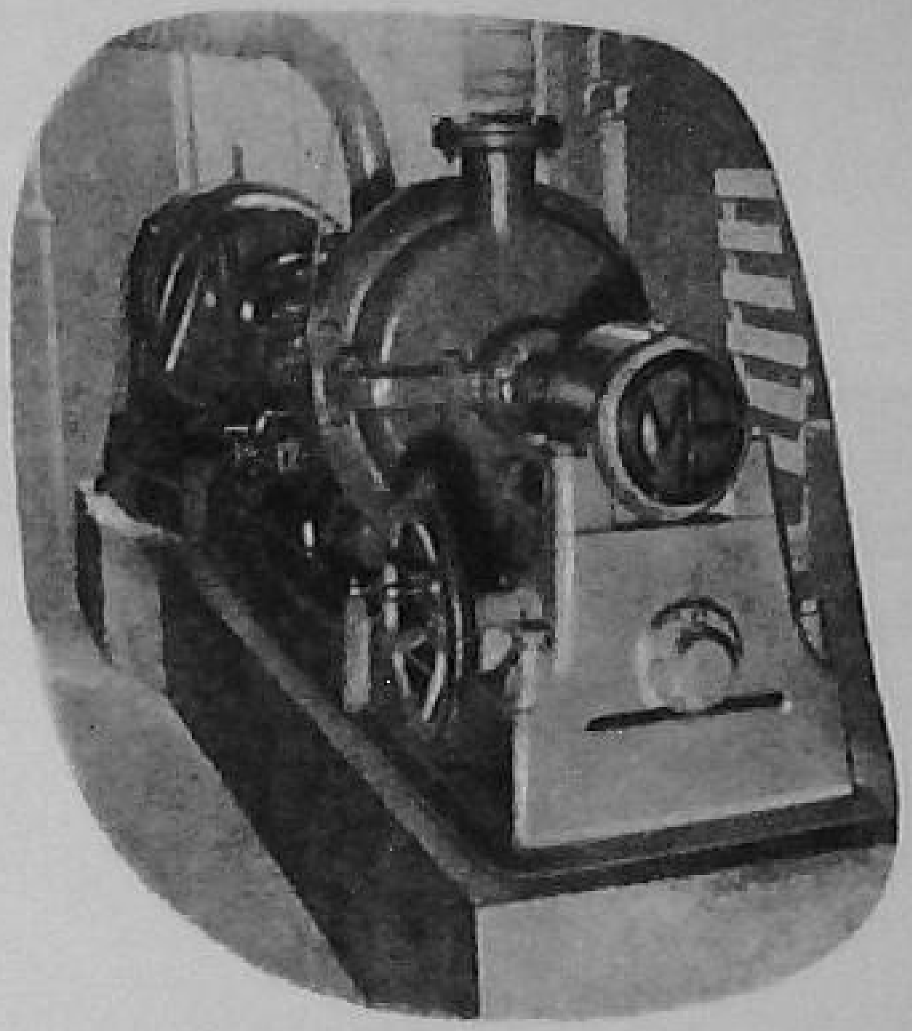

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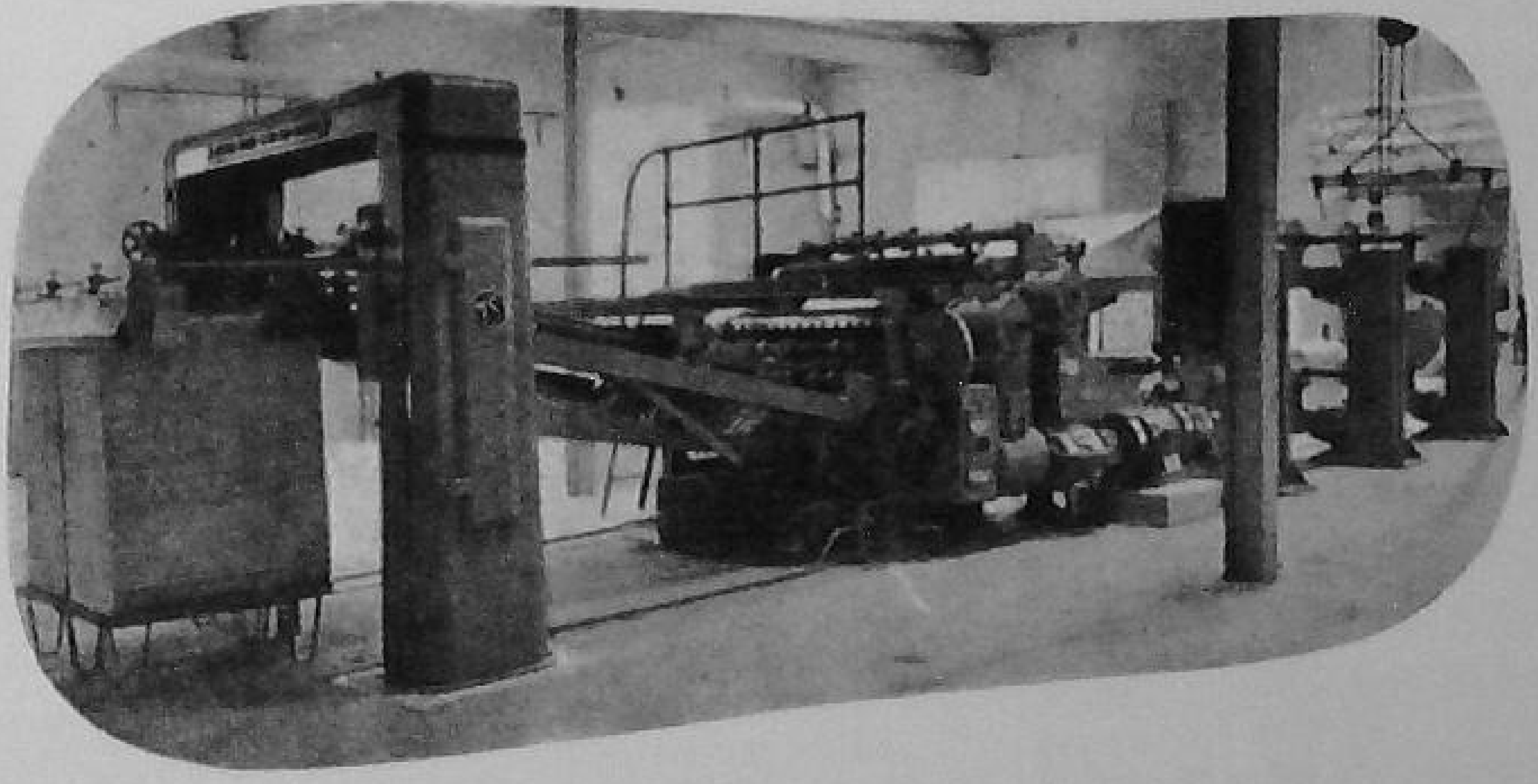

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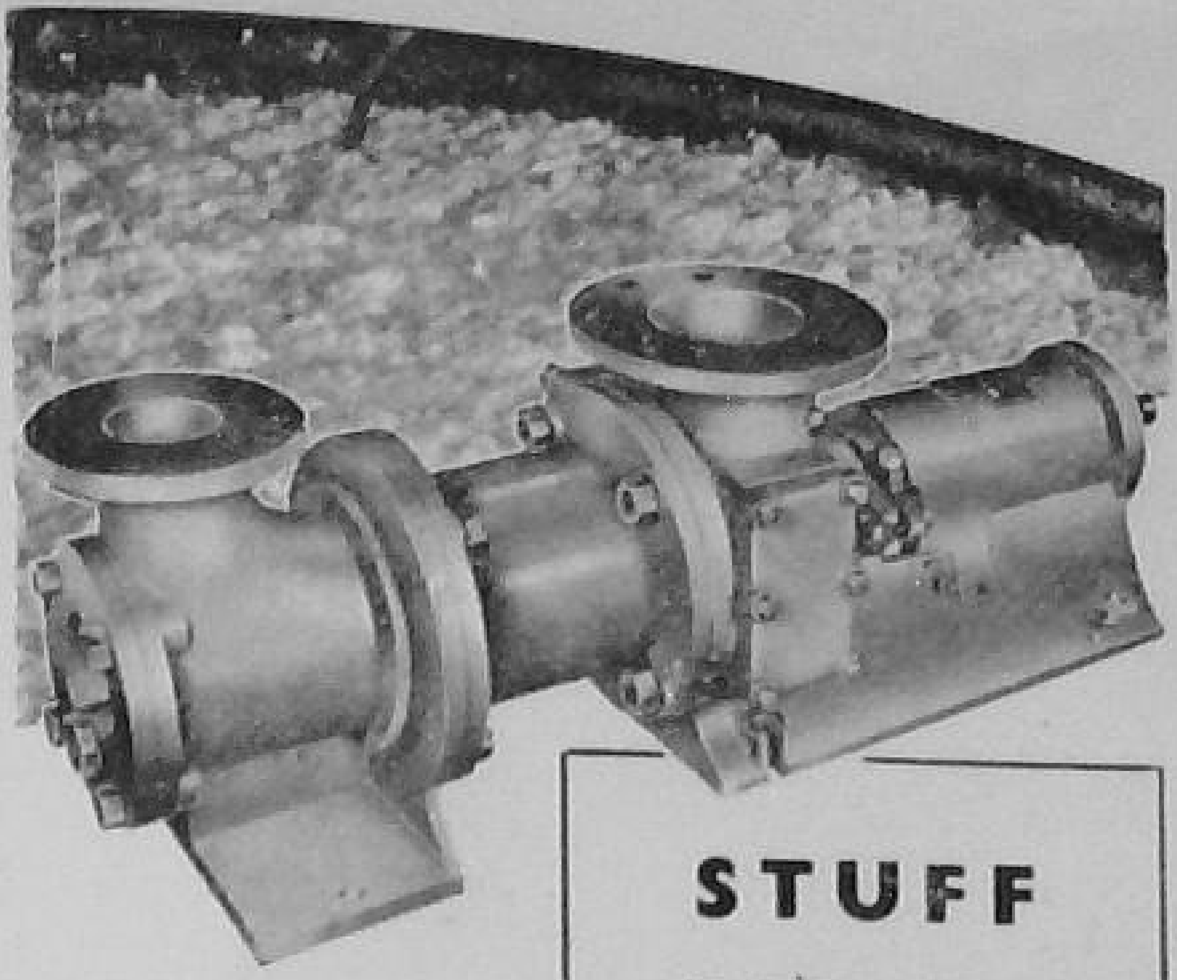

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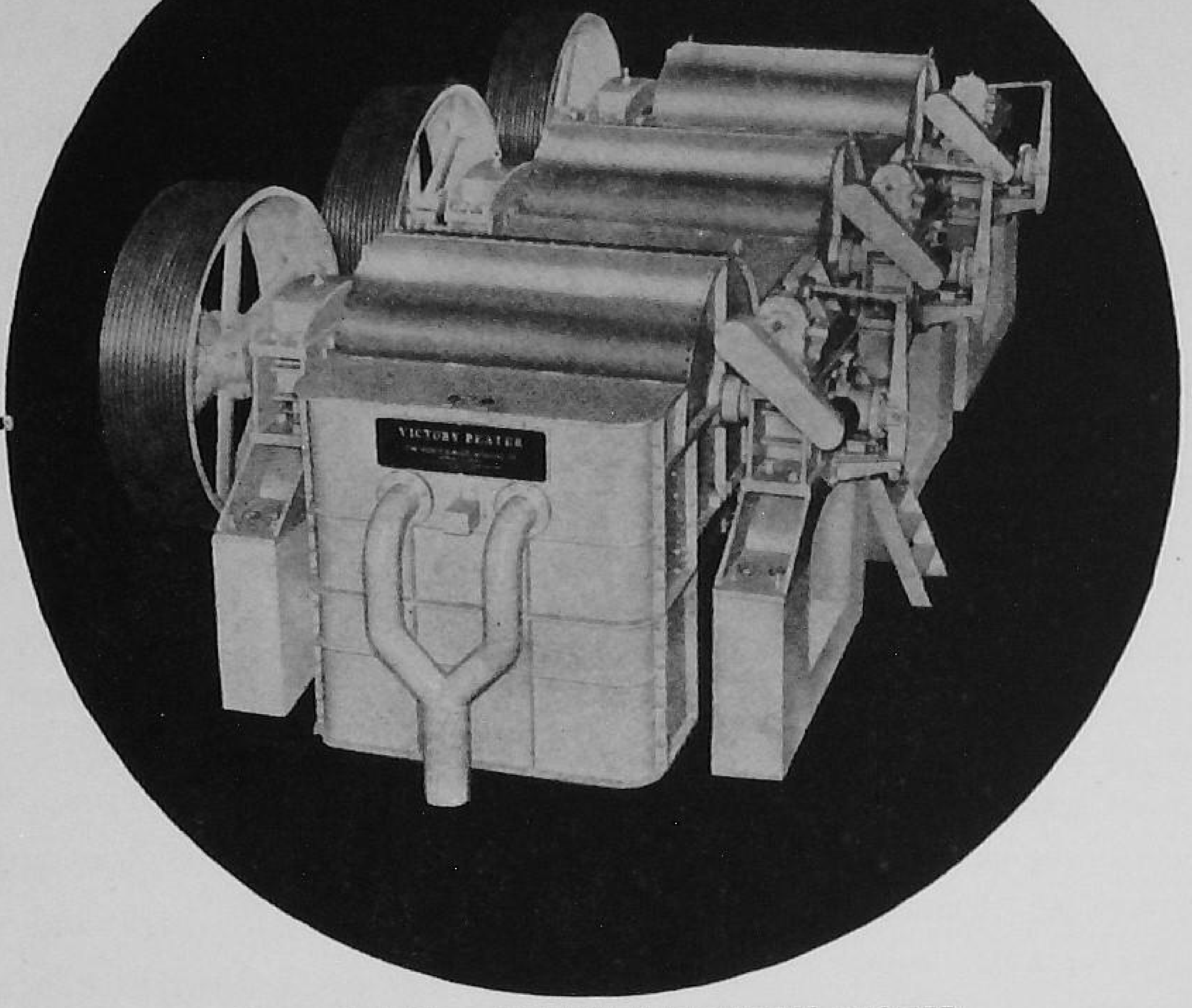

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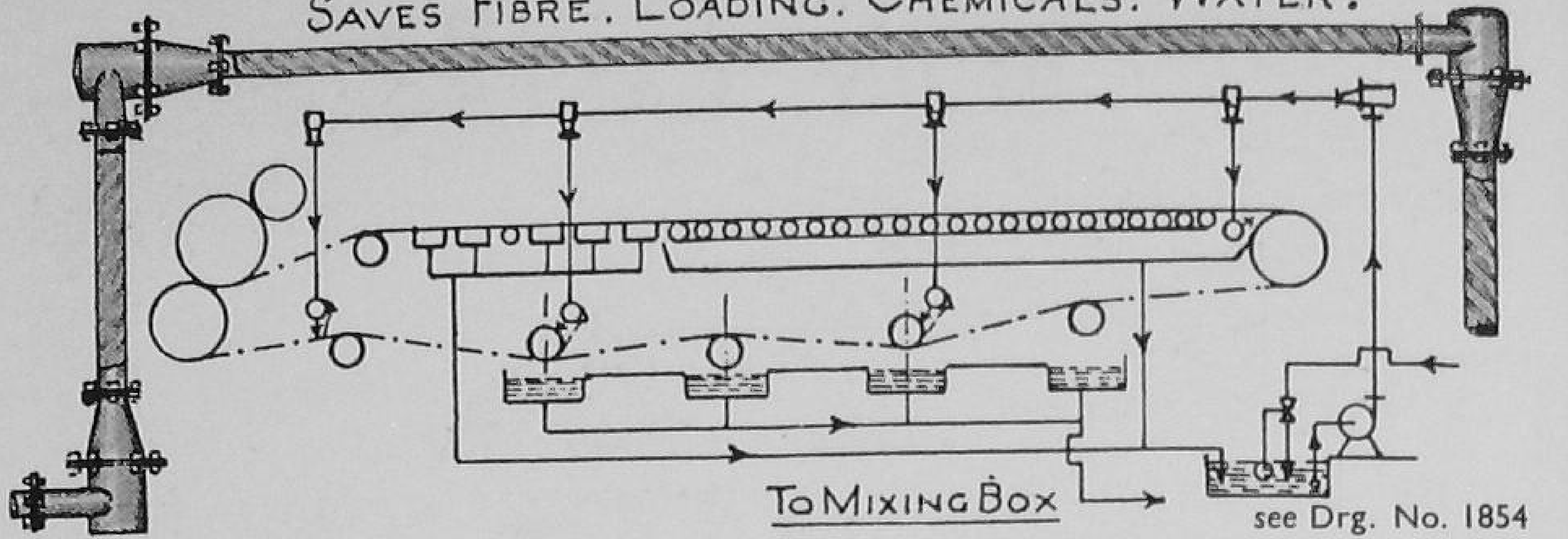

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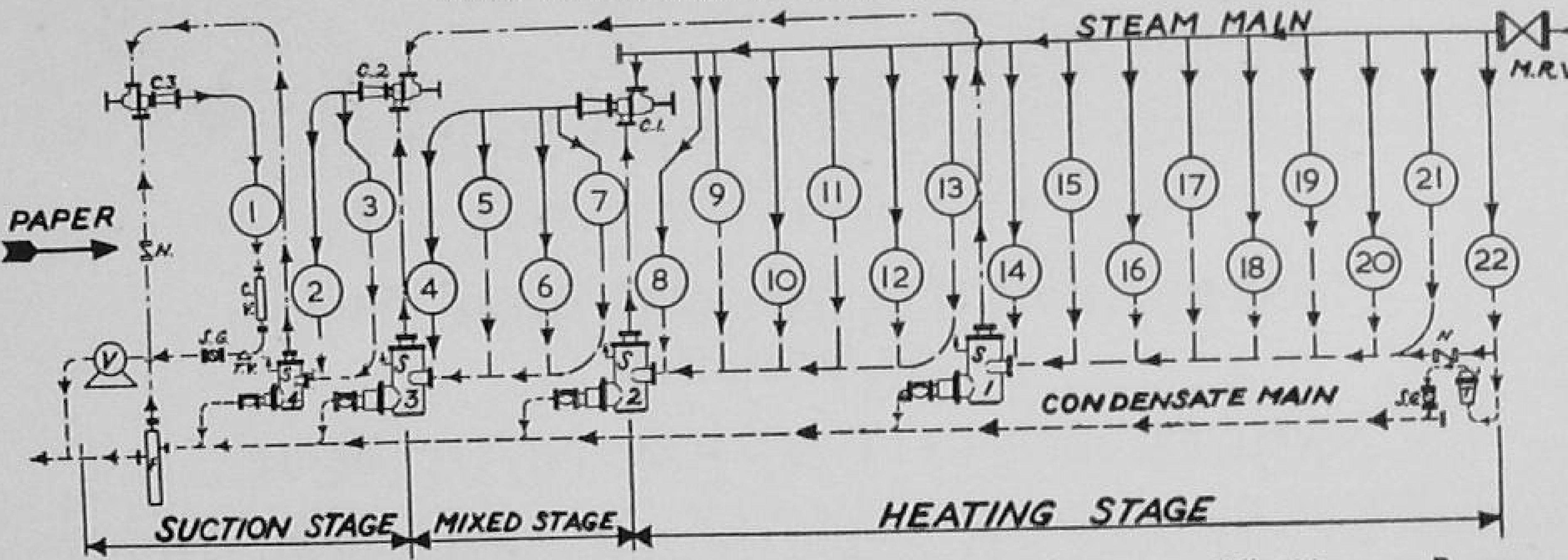

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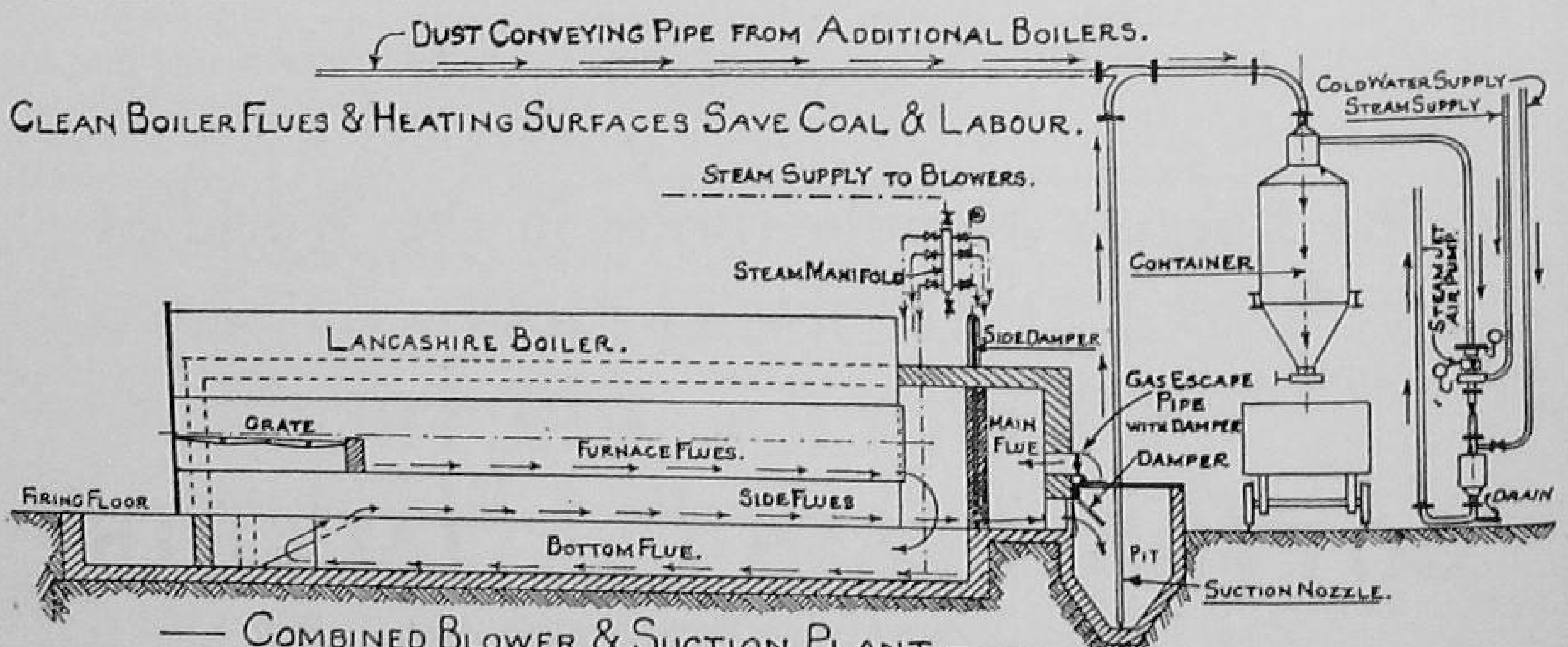

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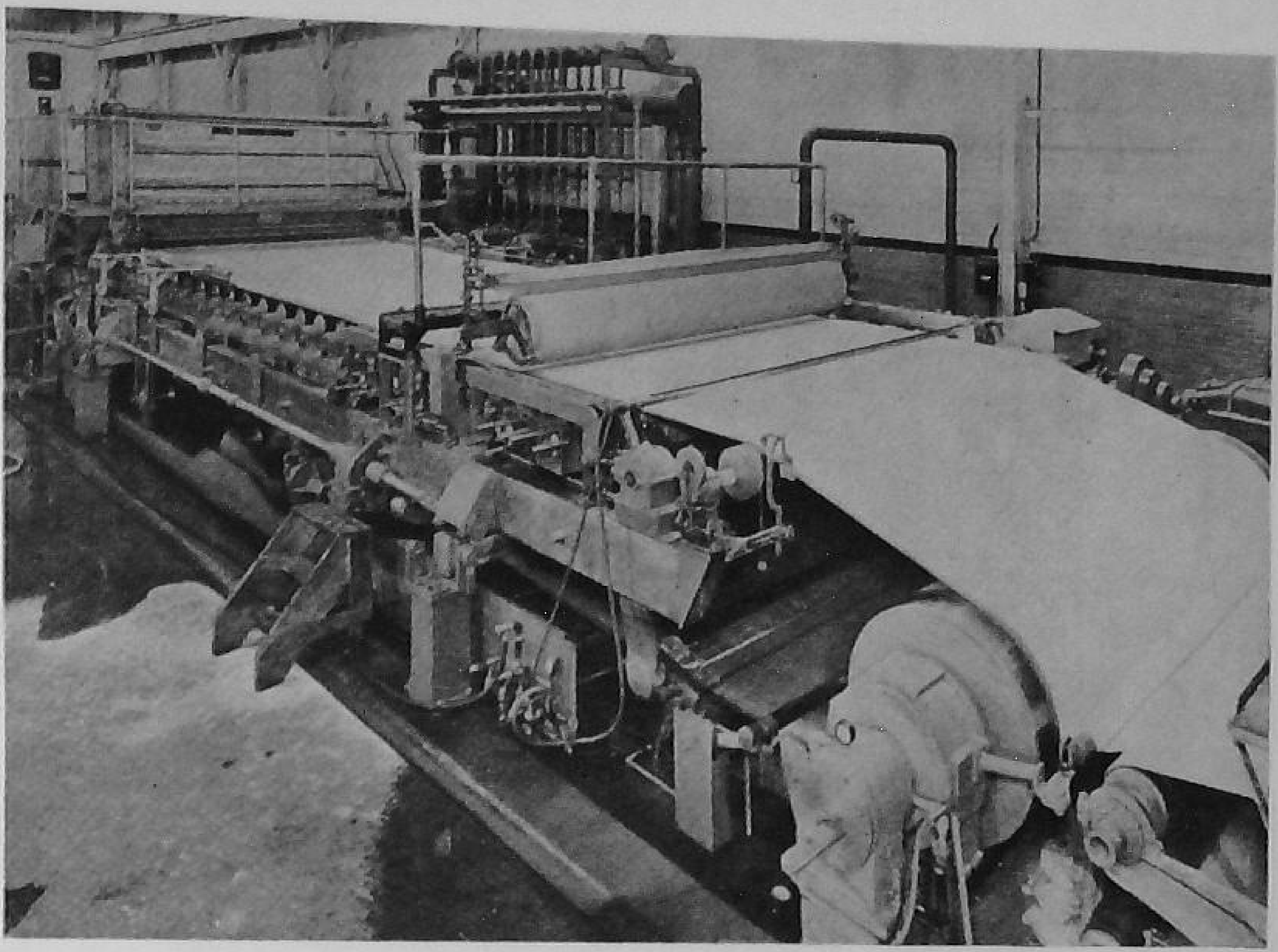

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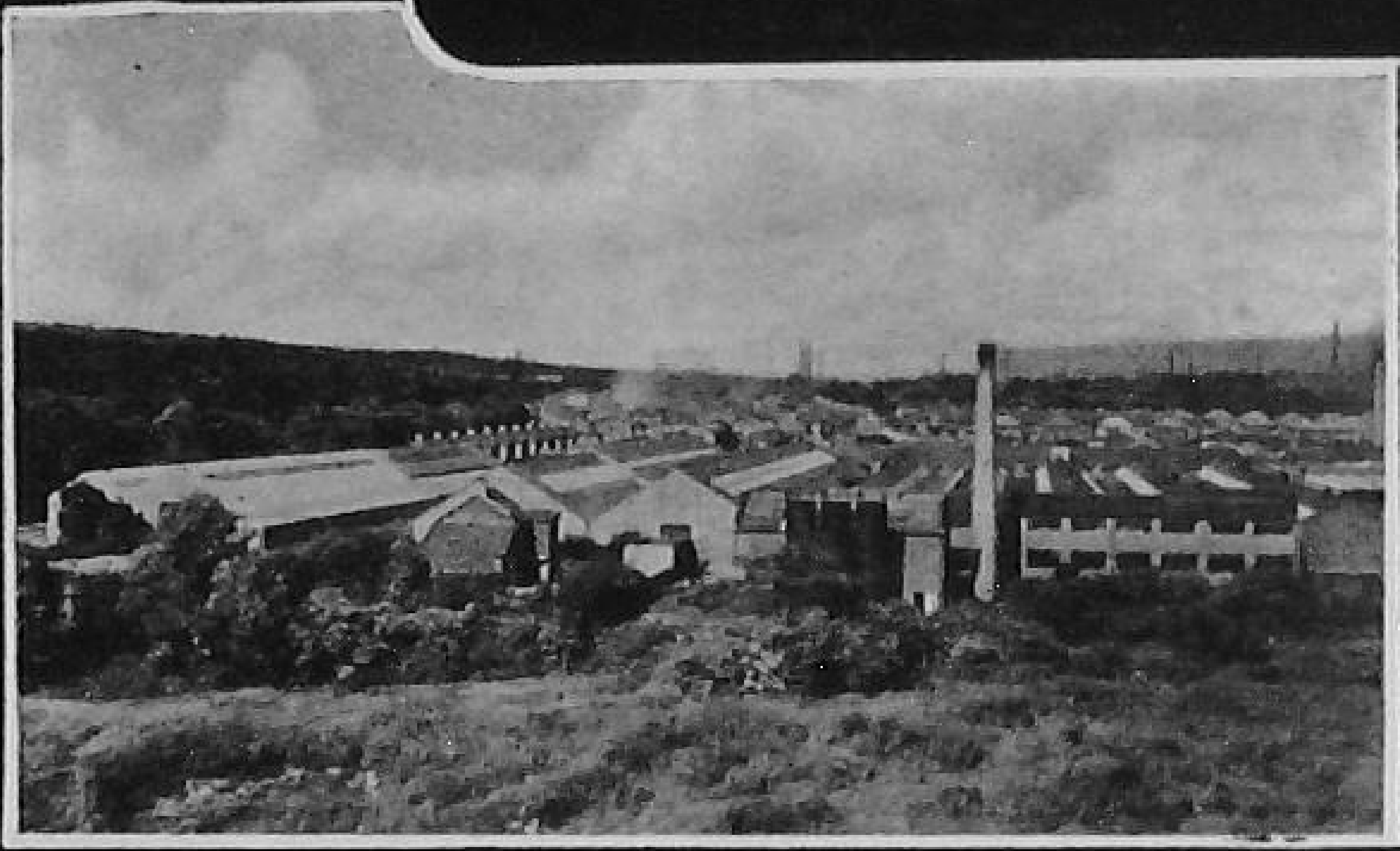

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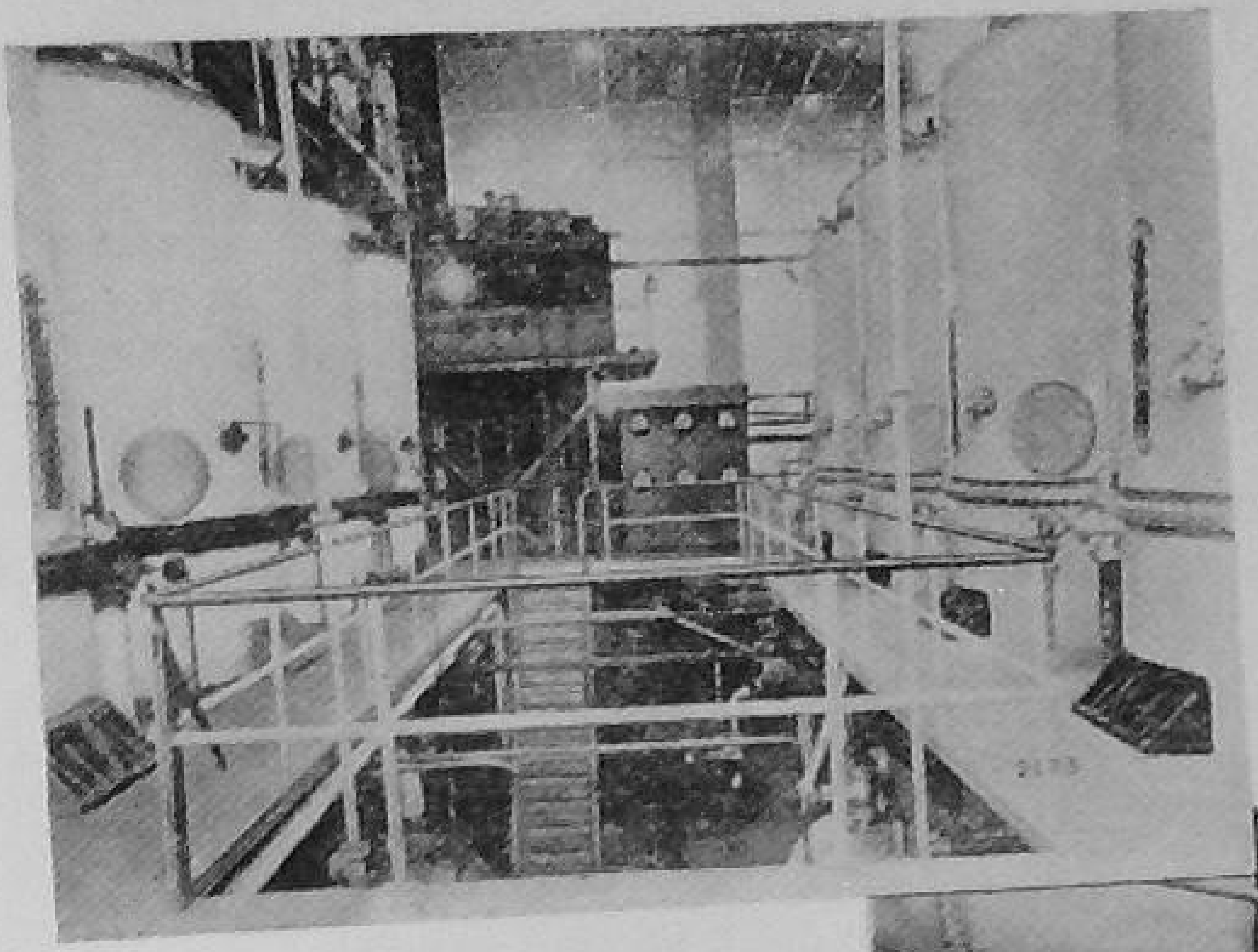
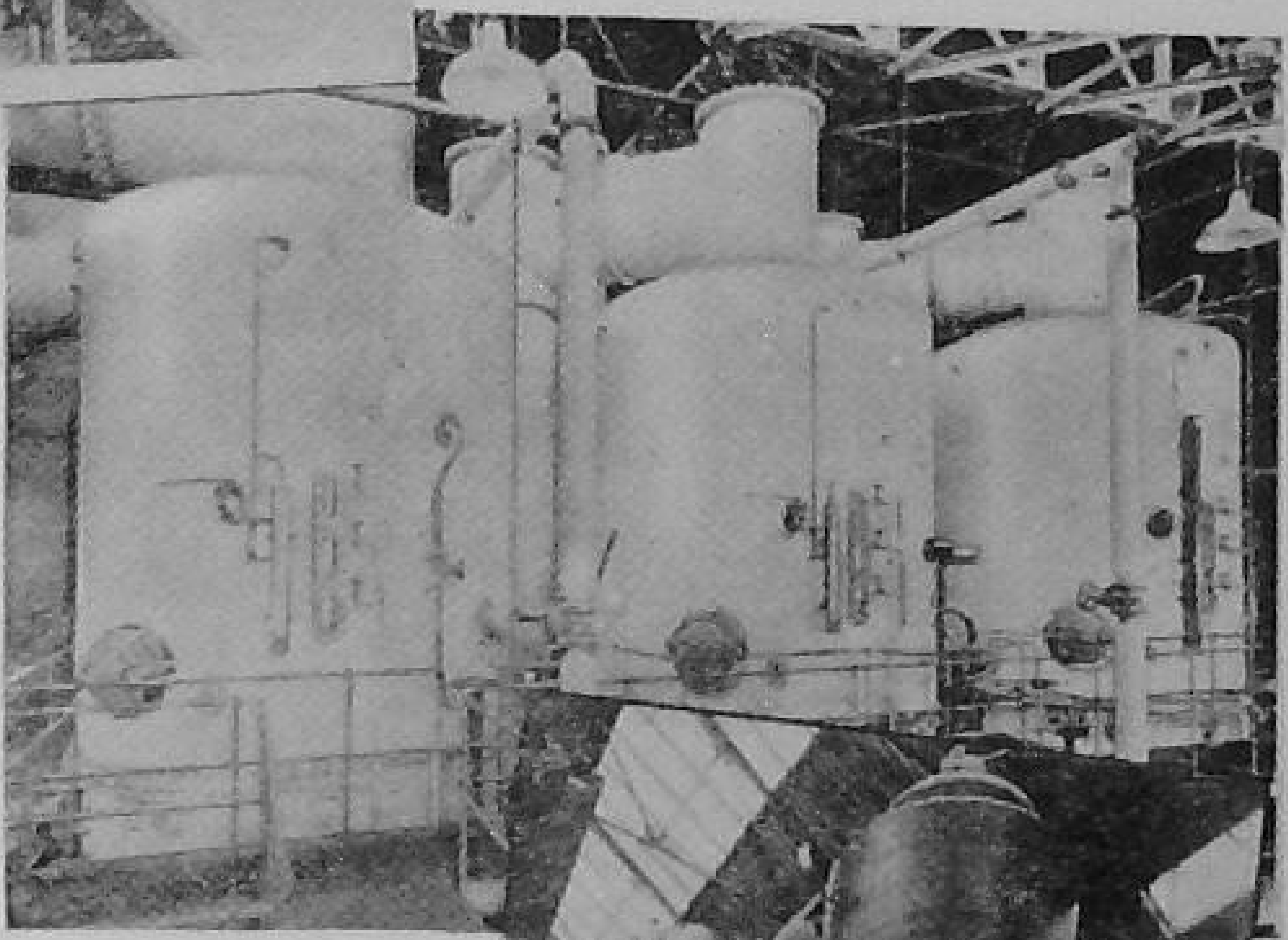
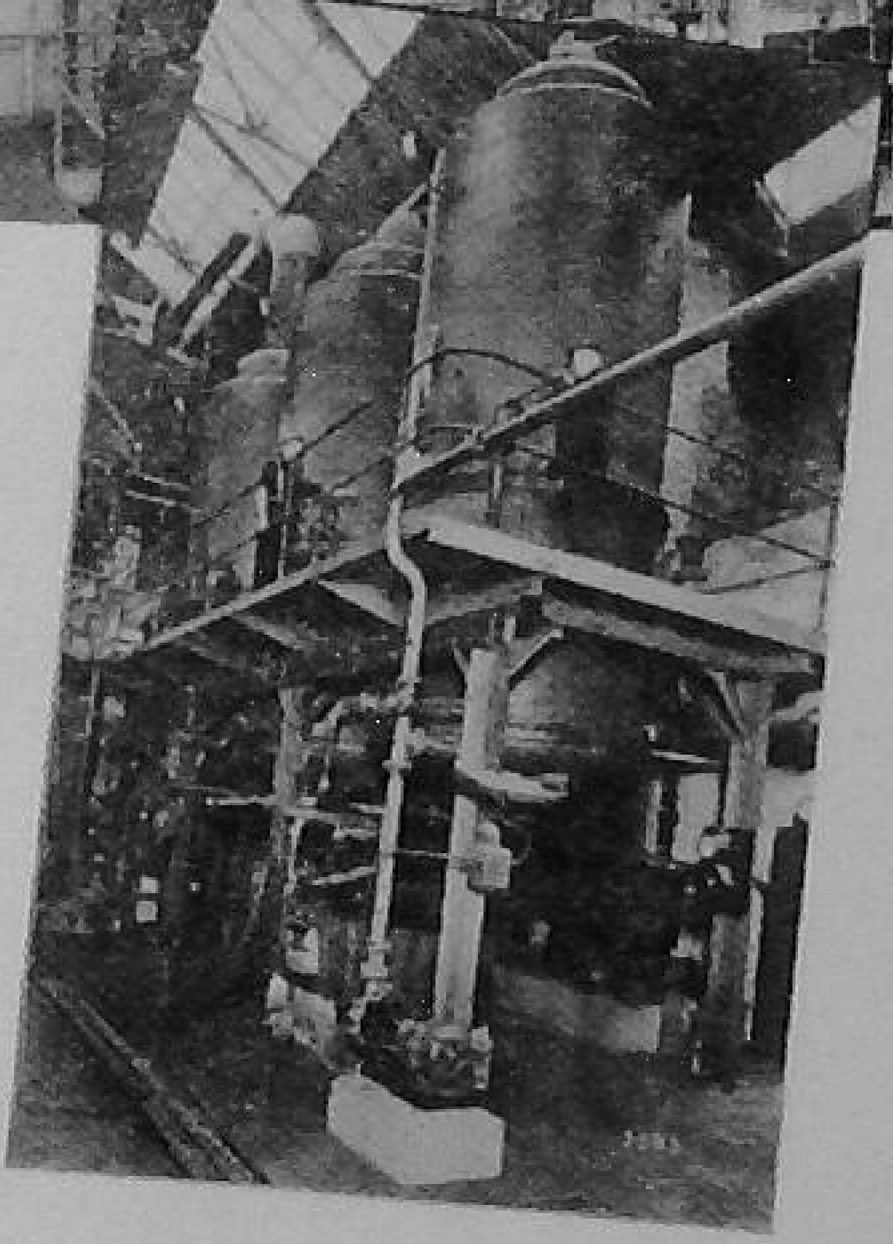


Left: 2 Scott Quadruple Effect Evaporators installed at a Dominion Mill. Centre: Triple Effect Evaporator for recovered caustic solution. Below: Triple Effect Vacuum Evaporator for esparto black liquor.





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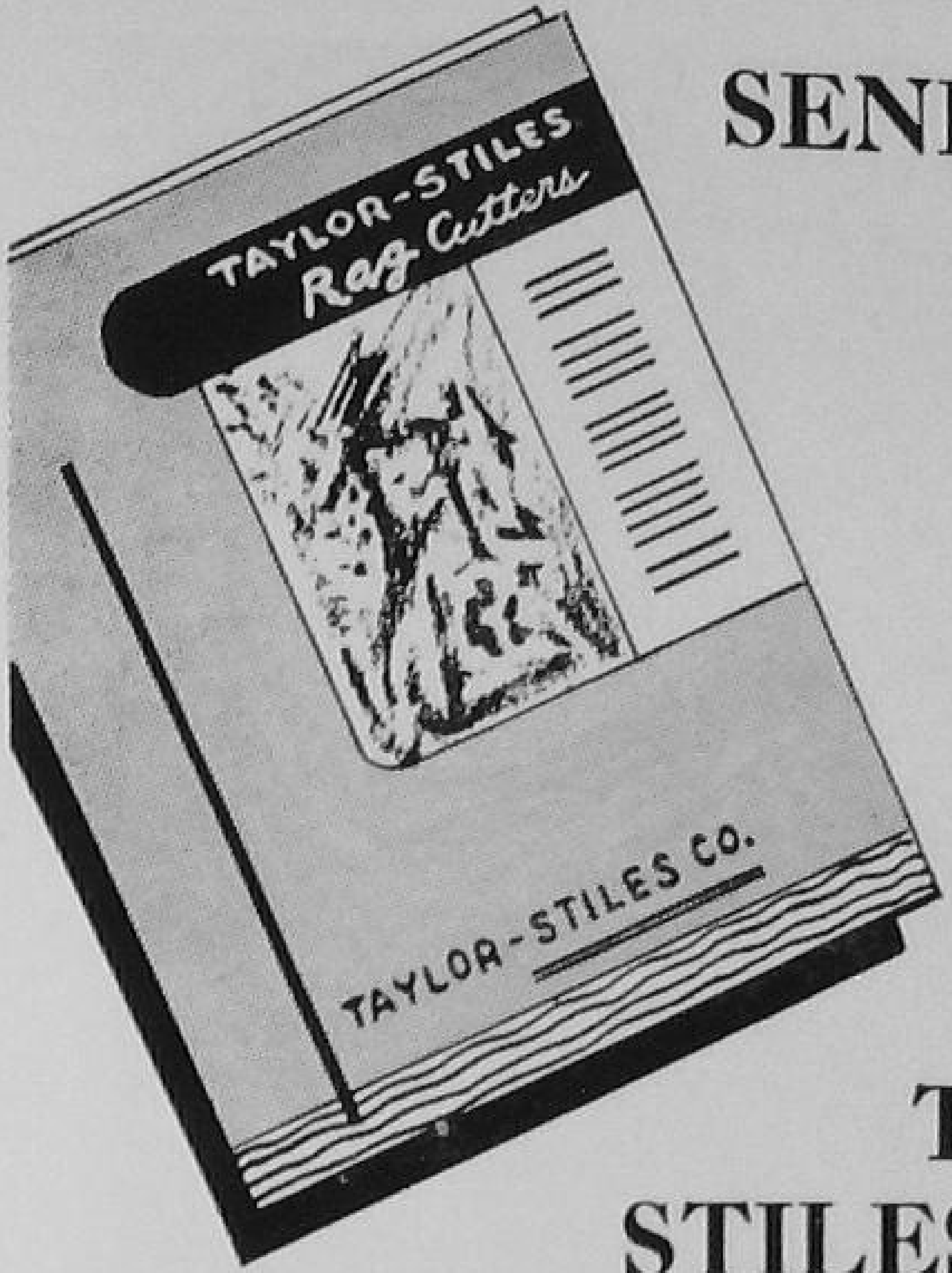

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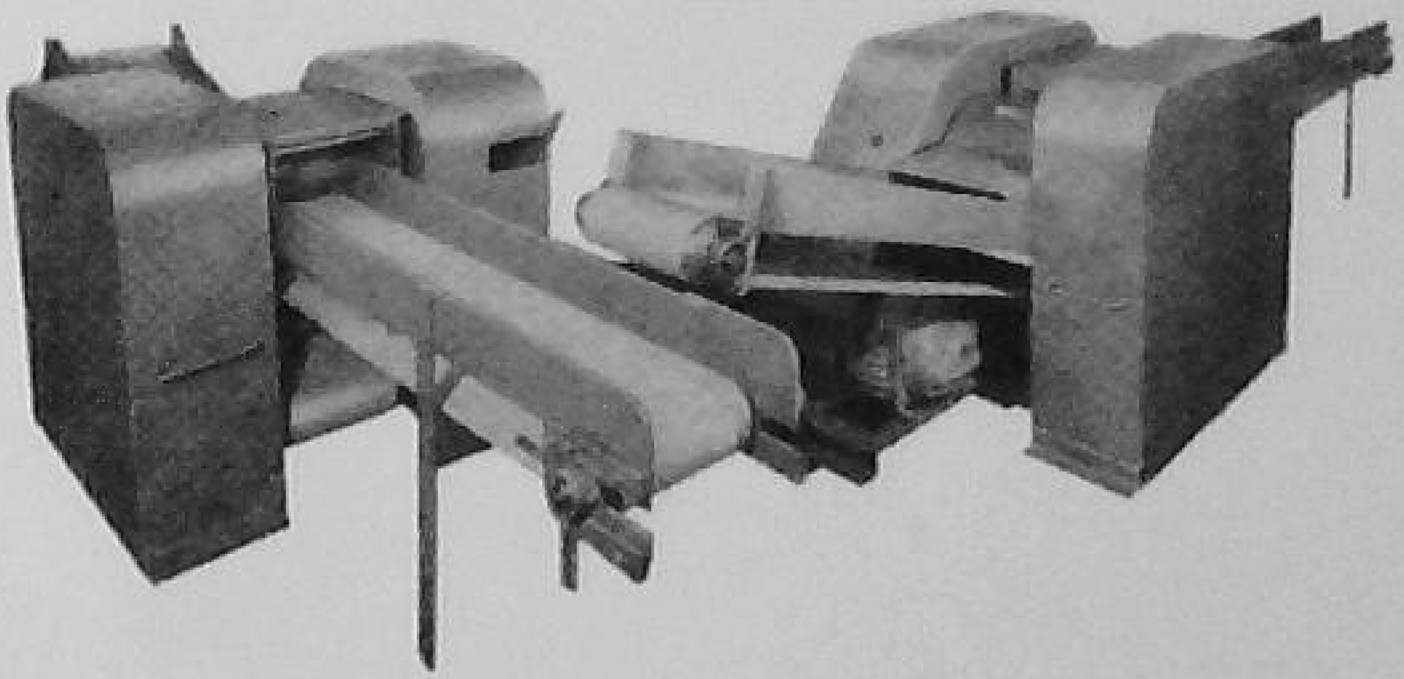

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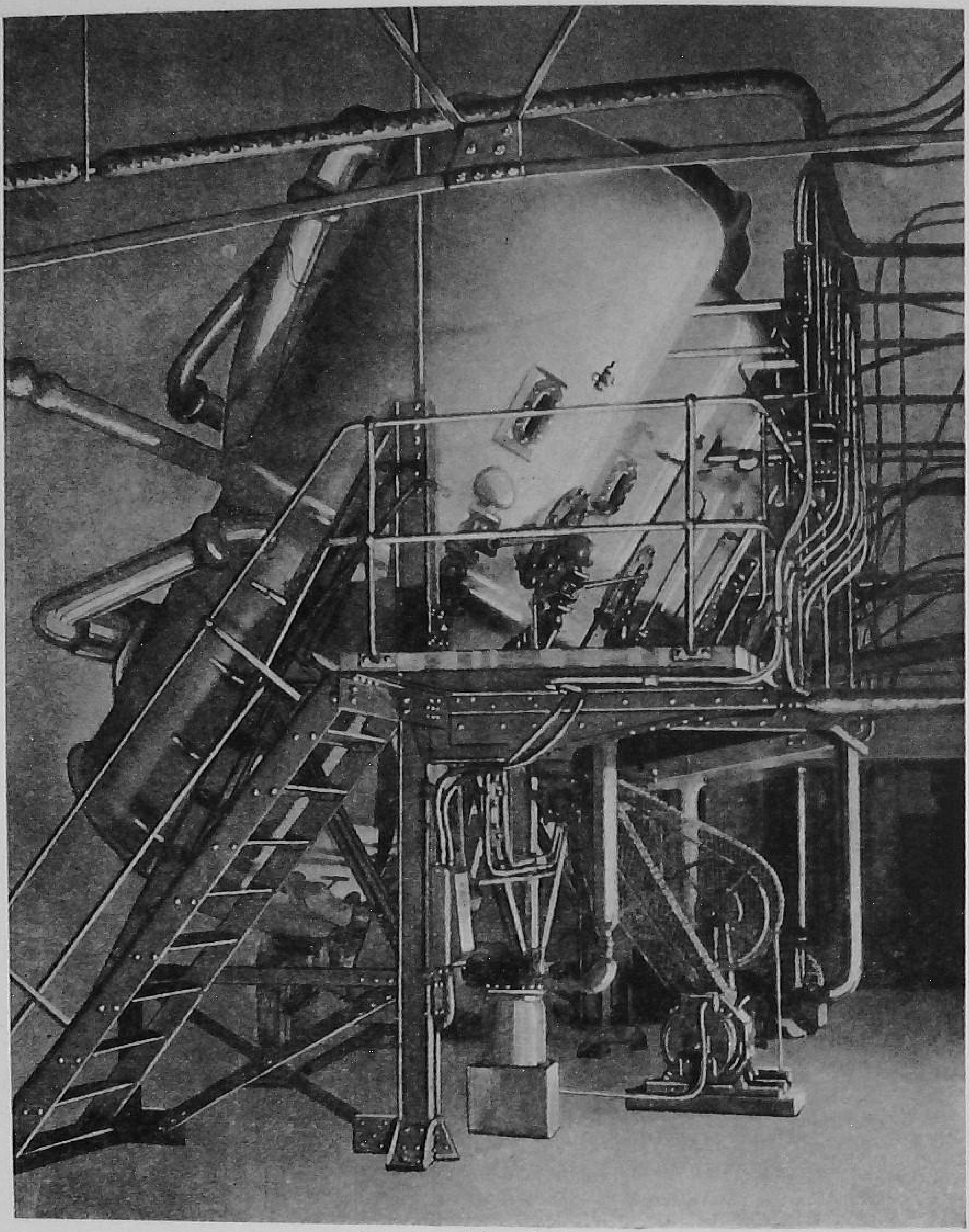

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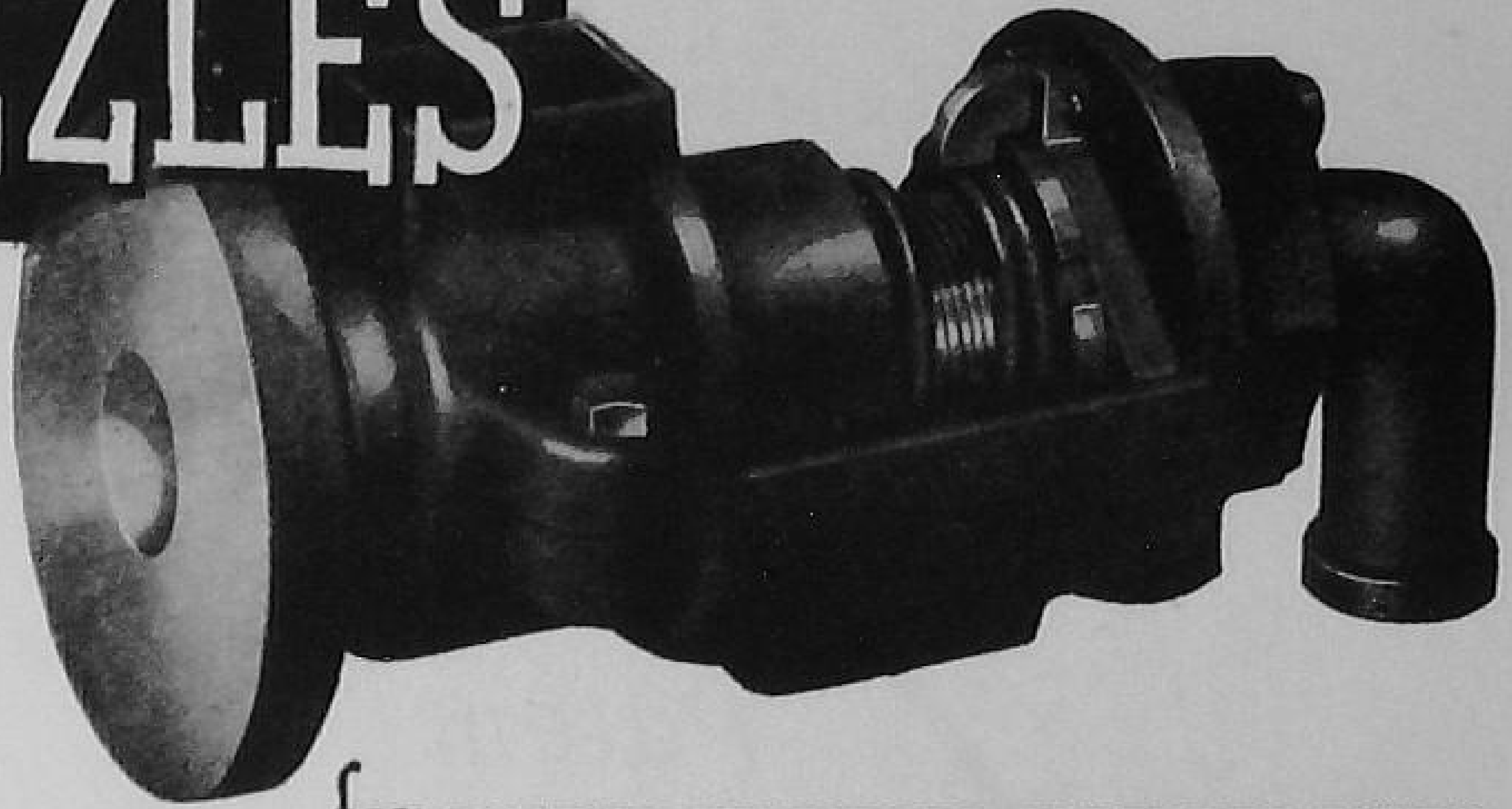

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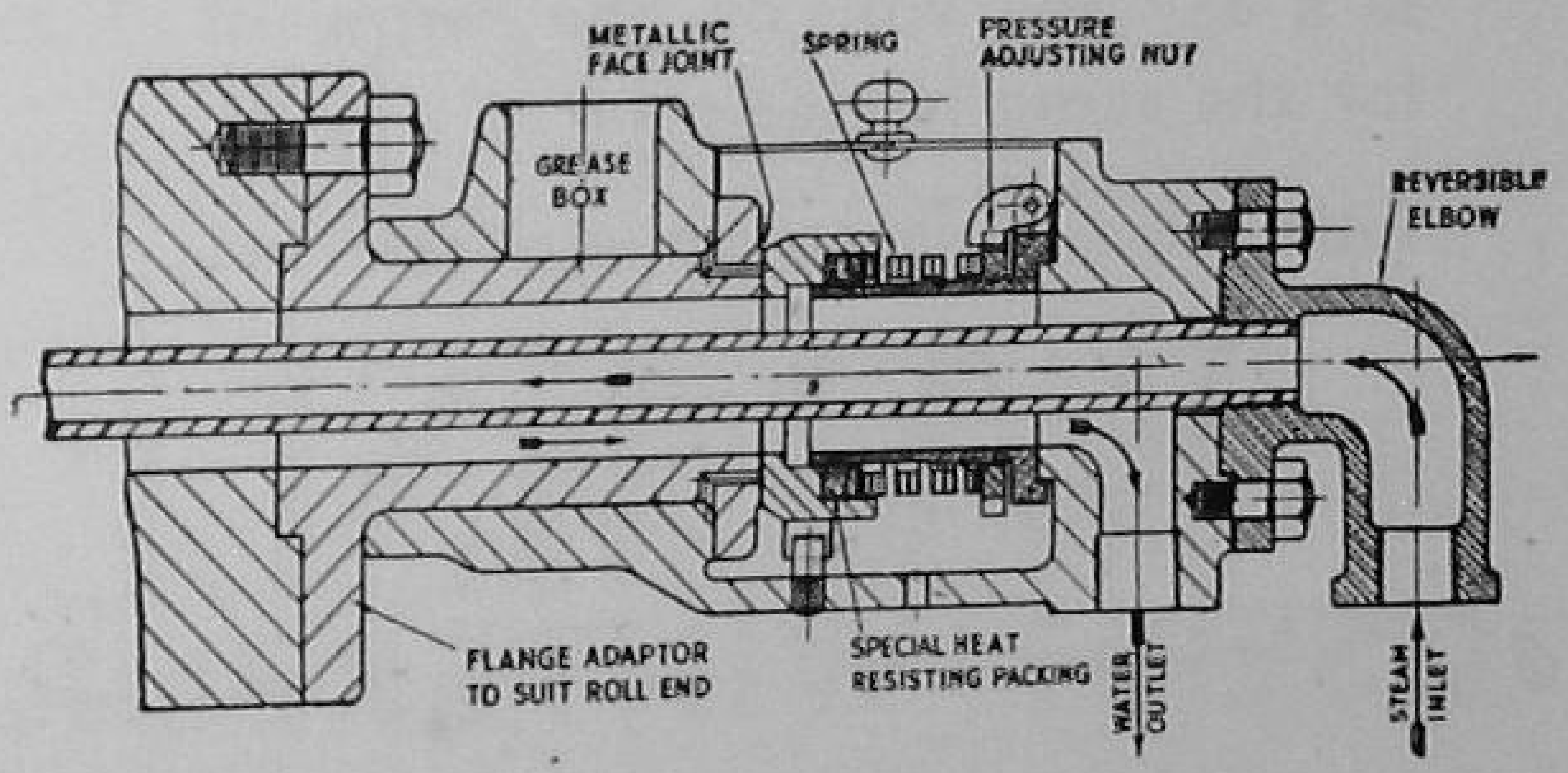

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